NONPOINT SOURCE POLLUTION
PROBLEMS/SOLUTIONS

PROCEEDINGS
FIRST ANNUAL VIRGIN ISLANDS CONFERENCE
on
NONPOINT SOURCE POLLUTION

October 4-5, 1993

DEPARTMENT OF PLANNING AND NATURAL RESOURCES
COASTAL ZONE MANAGEMENT PROGRAM
ST. THOMAS, UNITED STATES VIRGIN ISLANDS

Roy E. Adams, Commissioner

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Janice D. Hodge, Chairperson
Planning Committeee

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PLENARY PRESENTATIONS

** Paper not available at time of printing.*

WELCOMING REMARKS

Honorable Alexander A. Farrelly,
Governor of the United States Virgin Islands

Commissioner Roy Adams, visiting guests and delegates, it is a pleasure for me to welcome you to our First Annual Virgin Islands Conference on Nonpoint Source Pollution. For those of you visiting us for the first time, I hope you can take a few moments from your busy schedule to enjoy what nature has blessed us with. For those of you who are from here, Please take some time to enjoy some of the beauty with our guests.

Nonpoint Source Pollution... what is it? If you are like me, someone not used to the latest environmental jargon, you also might be wondering what Non Point Source Pollution is. Over the past year or so, I have heard the term mentioned numerous times. I have been fortunate enough to have received a brief description from my wife, the CZM Program Manager of the Virgin Islands Department of Planning and Natural Resources.

I now know that these pollutants, which are an everyday part of our lives affect each of us on a personal level. Rainwater, seems harmless enough and something we all need. However, rainwater picks up pollutants from our well kept lawns, from our streets and farms and from construction sites. It is carried into our wetlands and oceans as well as our ground water. These days, I cannot look at the rain falling and enjoy it, because I now think of its effects as it cascades down the mountainsides and roads, wondering what is being picked up and where it will be deposited.

Construction practices also contribute to the degradation of our coastal waters and drinking water. A degraded ocean means a reduction or elimination of our fish habitats, degraded coral reef systems, and a reduction in plant populations. Cloudy polluted waters, also mean a reduction in recreational activities, since no one wants to swim in unsafe, unappealing waters.

Today's conference, "Non Point Source Pollution, Finding Solutions to Environmental Pollution", gives us all an opportunity to learn more about the problem. But even more important it enables us to come up with solutions. However, a two day conference can only begin to scratch the surface. I commend Commissioner Adams and the CZM Program for taking the first step in bringing these issues to the forefront for us to give them deep thought, and I hope all of us, particularly those in the building trades, and in agriculture, as well as all of our Government Departments, take heed and begin to plan their activities with this new awareness.

My administration has always been and continues to be committed to ensure our waters are clean, our beaches remain beautiful and we all enjoy a healthy environment. Through the Department of Planning and Natural Resources, we continue to put in place the mechanisms for managing, enhancing, and protecting our natural resources and coastal areas.

Last week, the CZM Commission voted to approve management plans for eighteen Areas of Particular Concern (APC's). This was no easy feat, and I wish to commend all those involved in this effort. The management plans and boundaries are being reviewed by my office, and will be forwarded to the Legislature for their approval and adoption. But, because the Senate is currently absorbed in consideration of the Fiscal year 1994 budget of the Virgin Islands, I requested they extend the time frame for their final approval of the 18 APC's. Deliberating over the budget is a process that is likely to extend to December. It is my belief a date of January 31, 1994, for APC approval is realistic and fair.

Our Land and Water Use Plan, our Territorial Park System, are all part of a major effort in ensuring a continuation and an enhancement of what we all call " Paradise." If we all commit ourselves to work together for the good of our beautiful islands, we can still preserve and protect the good we have.

Again, I welcome you to the conference, and I hope the information we share here will be of practical use to us all. Thank you.

INTRODUCTION

Honorable Roy E. Adams, Commissioner
Department of Planning and Natural Resources

As part of the Coastal Zone Act Reauthorization Amendments of 1990, Congress enacted a new section 6217 entitled "Protecting our Coastal Waters". This provision requires states with coastal zone management programs that have received Federal approval under section 306 of the Coastal Zone Management Act to develop and implement coastal nonpoint pollution programs.

Because the coastal nonpoint pollution control program must be approved by the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA), the Virgin Islands, as well as all other territories and states, must comply with mandates set forth by these federal agencies. Some of these mandates will require statutory changes in the VI code in order to make our program acceptable.

A Virgin Islands Nonpoint Source (NPS) Pollution Committee consisting of federal, territorial and local agencies has been established to address nonpoint source pollution. The Committee will review the various mandates of EPA and NOAA as they pertain to the virgin Islands and develop and implement Best Management Practices (BMPs) to control NPS pollution.

At this point in their progress, the NPS Committee finds it necessary to conduct this conference so that information about nonpoint source pollution can be shared with the public.

Through this conference we hope to provide the general public and specific groups, such as contractors, architects, farmers and marina operators with sufficient information so that they can begin to focus on the various methods by which they can each reduce or eliminate nonpoint source pollutants and so help to satisfy the requirements of the nonpoint source pollution control program. It is very important for us to have the full participation of all concerned as early in the development of this program as possible so that any amendments to the existing VI code or program recommendations will have the necessary cooperation of all who will be affected.

We do realize that nonpoint source pollution cannot be eradicated within a year or two. Effective management of NPS pollution is essential to maintain the high water quality that currently exists in the Virgin Islands. The major sources of pollutants that impair our waterbodies are erosion and sedimentation from site development, urban runoff, vessel wastes disposal, and failing septic systems.

As you will discover when you attend the various presentations, nonpoint source pollution impacts our environment in many ways. Loss of fishing, loss of habitat (for some endangered species), human health risks, and loss of tourism - our primary industry are just a few.

Because of the importance of our natural resources to our economy, and because we all strive for a clean healthy environment, it is imperative that we begin to address our environmental problems now. We in the Virgin Islands enjoy an environment that is far superior to many others, let us do what we can now, while we still have a chance, to maintain it and where possible improve it. Keep in mind that the purpose of this conference is to share ideas and information so that we can work cooperatively to maximize our efforts.

TERRITORIAL RULES & REGULATIONS
GOVERNING NONPOINT SOURCE POLLUTION

Benjamin I. Nazario

Division of Environmental Protection
Virgin Islands Department of Planning and Natural Resources

Non-point source is defined as pollution sources which are diffuse and do not have a single point of origin or are not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for non-point source are: agriculture, forestry, urban, mining, constructions, dams and channels, land disposal, and saltwater intrusion.

The first opportunity and consideration in any non-point source effort is source control. By their nature laws and regulations are normally addressed at a specific source. The Virgin Islands laws that are affected in the control of non-point source pollution are part of Titles 12, 19 and 29 of the Virgin Islands Code and its rules and regulations and are as follows:

TITLE 12 CONSERVATION:

CHAPTER 3 "TREES AND VEGETATION ADJACENT TO WATERCOURSES"

Establishes policy for the cutting or injuring of certain trees within certain confines to a watercourse and institutes a permit requirement for said activity and provides for enforcement by DPNR Environmental Enforcement Officers. Permits are issued by the Commissioner of the Department of Planning and Natural Resources (DPNR).

CHAPTER 5 " WATER RESOURCES CONSERVATION "

Establish policy and regulations for the protection, conservation and development of the water resources, both surface and underground water of the U. S. Virgin Islands. Applications and plans for groundwater use are reviewed and permits issued by the Division of Environmental Protection (DEP) of DPNR.

CHAPTER 7 " WATER POLLUTION "

Establish policy and regulations to conserve the waters of the VI, to protect and maintain, and improve the quality thereof for public water supplies, for propagation of wildlife, fish and aquatic life, and for domestic, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the VI without first receiving necessary treatment or corrective action to protect the legitimate beneficial use of such water; to provide for the prevention, abatement and control of new or existing water pollution; to authorize the implementation of the Federal Water Pollution Control

Act (FWPCA) and other amendatory acts.

Territorial Pollution Discharge Elimination System (TPDES) - a system of requirements to obtain permits for commencement or continuation of any discharge of pollutants to surface waters. Applications and plans are reviewed and permits issued by DEP.

Water Quality Certification (WQC) - Certifications are issued by DEP.

This chapter needs to be revised and updated to address the federal requirements of the National Storm Water Program which complements the TPDES permit system. The system focuses on the municipal and industrial pollution prevention to help control storm water pollution and involves issuing permits to certain municipalities and industries to control storm water pollution.

CHAPTER 13 " ENVIRONMENTAL PROTECTION "

Earth Change plans and permits required before any real property is cleared, graded, filled or otherwise disturbed for any purpose or use including but not limited to erection of any building or structure, the quarrying of stone or the construction of roads and streets. Plans are reviewed and permits issued by the Permits Division of DPNR.

CHAPTER 17 " OIL SPILL PREVENTION & POLLUTION CONTROL "

Establish policy to regulate the transfer, storage and transportation of pollutants and other such products that pose threat of great damage and damage to the environment, to owners and users of shore front property, to public and private recreation, to citizens of the territory and other interests deriving livelihood from marine related activities and to the beauty of the territorial shoreline. The provisions of this chapter are administered by DPNR.

This statute and its rules and regulations need to be revised and updated to include the requirements of the Oil Pollution Act of 1990, the Underground Storage tank (UST) and Above-ground Storage Tank (AST) provisions.

CHAPTER 19 " PESTICIDE "

Establishes policy to regulate the use and application of pesticides to control pests. Pests are defined as any insect, rodent, nematodes, fungus weed or any other form of terrestrial or aquatic plant or animal life or virus, bacteria, or other microorganisms (except viruses, bacteria, or other microorganisms on or in living man or the living animals) which is declared by the Commissioner. Provision of this chapter are administered by DPNR. Certification is issued by the Division of Environmental Protection (DEP) of DPNR. This statute and its rules and regulations need to be revised and updated.

CHAPTER 21 " COASTAL ZONE MANAGEMENT ACT "

The Coastal Zone Management Act (CZM) mandates by policy to protect, maintain, preserve and where feasible enhance and restore the overall quality of the environment; to provide economic development and growth; to assure orderly balanced utilization and conservation of resources, etc., to conserve ecologically significant resource areas, and preserve the function and integrity of reefs, marine meadowlands, saltponds, mangroves and other significant natural areas; to maintain or increase coastal water quality through control of erosion, sedimentation, runoff siltation and sewage discharge. Applications and plans are reviewed by the Permits Division of DPNR and permits are approved by the island CZM Committee or the Commissioner of DPNR depending on whether the application is for a major or minor permit.

TITLE 19 HEALTH:

CHAPTER 53 " SANITATION "

Provides policy for the regulation of discharges from building or premises to existing sanitary sewers or public sewers; the contents of cesspools or septic tanks into public gutters; the collection and/or treatment of refuse deposition of materials or waste products that cause the surrounding air, land or water to be contaminated or polluted in such a manner as to injure public health; design, location and installation of sewage treatment systems. This statute and its rules and regulations need to be revised and updated. Applications and plans are reviewed and permits issued by DEP.

CHAPTER 55 " SEWAGE DISPOSAL "

Establishes policy to regulate design, location and installation or sewage disposal systems. Institutes a Sanitary Facilities Fund and promulgates the collection of fees for the use of the public sewer system.

Territorial Rules and Regulations Governing Nonpoint Source Pollution

CHAPTER 56 " SOLID AND HAZARDOUS WASTE MANAGEMENT "

Establishes policy and regulation for the proper storage, transportation and disposal of solid and hazardous waste in the Virgin Islands; to promote and facilitate, wherever possible, resource conservation and recovery; to impose the duty of contribution to public cleanliness and appearance in order to promote public health, safety and welfare. this chapter provides for the proper disposal of derelict vehicles.

This chapter is presently being revised and up dated to reflect the requirements of the new federal landfill criteria.

TITLE 29 PUBLIC PLANNING AND DEVELOPMENT:

CHAPTER 3 " VIRGIN ISLANDS ZONING AND SUBDIVISION "

Establishes standards and policies concerning development of land which may be used in achieving the goals of the General Development Plan of the Virgin Islands. the purpose is to promote health, safety, ,morals and general welfare of the community by establishing regulations and conditions governing the erection of buildings, structure and use of land and water.

CHAPTER 5 " BUILDING CODE "

Establishes policy and regulations to safeguard life and limb, property, and public welfare, through the establishment of minimum building requirements for structural strength and stability. Has specific provisions for flood control and protection,sanitary sewage systems, etc. Plans are reviewed and permits issued by the Permits Division of DPNR.

All of these statutes and Rules and Regulations are of the 1970's vintage. They require revision and updating to reflect present amendments and state of the technology. We in DEP are present working to address some of these short comings for instance we're working to revise the Pesticides laws, the solid waste to comply with the federal laws for landfills, the Air pollution laws to comply with the Clean Air Act of 1990, the Oil Pollution Act 1990.

Non-Point Source Program - DEP is presently working with the VI Soil Conservation District on a project partially funded by EPA to study storm water and septic tank regulations.

* * *

Federal Rules and Regulations Governing Nonpoint Pollution

Malcolm L. Henning

U.S. Environmental Protection Agency, Region II

New York, New York

In 1987 when Congress amended the Clean Water Act (CWA), it was clear that one of their goals was to establish a national policy on the control of Nonpoint Source (NPS) pollution and that a national Nonpoint Source pollution control program be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution.

Section 319 of the Clean Water Act, is the national program enacted by Congress to control nonpoint sources of water pollution.

Section 319 required two major reports to be completed by the States/Territories: A state/territory Assessment Report describing the State's NPS problems and a state/territory Management Program explaining what the state plans to do in the next four fiscal years to address their NPS problems. The U.S. Virgin Islands has an EPA approved Assessment Report and Management Program.

What is Nonpoint Source Pollution?

For the purpose of implementing the NPS provisions in the CWA, NPS pollution is defined as follows:

<u>Nonpoint Source Pollution:</u> NPS pollution is caused by diffuse sources that are not regulated as point sources and normally is associated with agricultural, silvicultural and urban runoff, runoff from construction activities, etc. Such pollution results in the human-made or human-induced alteration of the chemical, physical, biological, and radiological integrity of water. In practical terms, nonpoint source pollution does not result from a discharge at a specific, single location (such as a single pipe) but generally results from land runoff, precipitation, atmospheric deposition, or percolation. It must be kept in mind that this definition is necessarily general; legal and regulatory decisions have sometimes resulted in certain sources being assigned to either the point or nonpoint source categories because of considerations other than their manner of discharge. For example, irrigation return flows are designated as "nonpoint sources" by Section 402(l) of

the Clean Water Act, even though the discharge is through a discrete conveyance.

Examples of NPS Pollution

1 Nonpoint Sources

10 Agriculture
- 11: Non-irrigated crop production
- 12: Irrigated crop production
- 13: Specialty crop production (e.g., truck farming and orchards)
- 14: Pasture land
- 15: Range land
- 16: Feedlots - all types
- 17: Aquaculture
- 18: Animal holding/management areas

20 Silviculture
- 21: Harvesting, reforestation,
- 22: Forest management
- 23: Road construction/maintenance

30 Construction
- 31: Highway/road/bridge
- 32: Land development

40 Urban Runoff
- 41: Storm sewers (source control)
- 42: Combined sewers (source control)
- 43: Surface runoff

50 Resource Extraction/Exploration/Development
- 51: Surface mining
- 52: Subsurface mining
- 53: Placer mining
- 54: Dredge mining
- 55: Petroleum activities
- 56: Mill tailings
- 57: Mine tailings

60 Land Disposal (Runoff/Leachate From Permitted Areas)
- 61: Sludge
- 62: Wastewater
- 63: Landfills
- 64: Industrial land treatment

70 Hydrologic/Habitat Modification
- 71: Channelization
- 72: Dredging
- 73: Dam construction
- 74: Flow regulation/ modification
- 75: Bridge construction
- 76: Removal of riparian vegetation
- 77: Streambank modification/ destabilization

80 Other
- 81: Atmospheric deposition
- 82: Waste storage/storage tank
- 83: Highway maintenance and runoff
- 84: Spills
- 85: In-Place contaminants
- 86: Natural

90 Source unknown

65: On-site wastewater systems (septic tanks, etc.)
66: Hazardous waste

Nonpoint Source Financial Provisions

The CWA of 1987 provides four new sources of funds in the CWA, on an annual basis, to support the implementation of a State's nonpoint source Management Program.

(1) Section 319(h) authorize grant funds to support protection of both surface and ground water quality. These funds are not to be used as a general subsidy or for cost sharing to support implementation of best management practices by individuals, except for demonstration purposes.

(2) Section 205(j)(5) provides a set-aside of 1% of each State's annual construction grant allocation or 100,000, whichever is grater, to be used for the preparation and implementation of the State's management program. Section 205(j)(5) funds are now provided under Section 604(b) funding requirements.

(3) In addition, nonpoint source control efforts may be financed thought the Governor's 20% discretionary set-aside of construction grant funds under amended section 201(g)(1).

(4) Finally, new State revolving funds established by Title VI may be used for loans, including loans to public agencies or individuals, to implement NPS management programs, for instance, 601 and 603 water pollution Control funds.

The use of each funding source is subject to certain statutory restrictions and limitations. The flow of Federal funds in support of State management program activities under section 319 is conditioned based on the EPA approval of the State's Management Program. The single exception to this rule are funds set-aside from construction grant allocations under Section 205(j)(5). These funds may be used to develop the management program and then, later, to help implement the State's management program.

The Federal share of implementing a nonpoint source management program under Section 319(h) shall not exceed 60% in any fiscal year. Section 319(h) funds may not be awarded unless the State has demonstrated satisfactory progress in meeting the schedule set out in the approved nonpoint source management program.

In addition to Section 319, the Clean Water Act of 1987 also included Nonpoint Source provisions in other CWA programs.

Section 314 Clean Lakes Program is to protect the quality of the country's publicly owned freshwater lakes by controlling sources (point or nonpoint) of pollution affecting them and by restoring lakes which have deteriorated in quality.

Lakes are funded under three mechanisms. They are:

1. State Lake Classification Study: The state classifies by trophic condition all its publicly owned freshwater lakes needing restoration and protection. Then the state lists these lake projects in order of priority. Funding assistance may go to $100,000 or 70% of the cost.

2. Phase I Diagnostic Feasibility Study: This study determines the cause of the lake problems, evaluates possible solutions, and recommends the most feasible program to protect and restore the lake's quality. Again, the funding assistance is 70% federal and 30% territory or local, to a maximum of $100,000.

3. Phase II Implementation: The implementation phase put the recommendations into operation. The funding of phase II is 50/50, however, the state/local share can include in-kind services.

Section 320 National Estuary Program is to restore and maintain the chemical, physical, and biological integrity of an estuary by addressing both point and nonpoint sources of pollution.

The Governor of any state/territory may nominate to the Administrator of EPA an estuary of national significance and request that a management conference develop a comprehensive management plan for the estuary.

Other Federal Rules and Regulations Governing Nonpoint Source Pollution.

We have talked a little about the Section 319 Nonpoint Source program and other Sections under the CWA, now I will discuss some of the other federal laws that governs Nonpoint Source pollution.

1. The Safe Drinking Water Act of 1984: The Safe Drinking Water Act required that national standards be established for drinking water. The law requires two things for all community drinking water systems: (a) Routine monitoring for several pollutants, and (b) Compliance with minimum standards. The Environmental Protection Agency (EPA) is required to set standards for 100 pollutants, including several toxic chemicals.

2. EPA Stormwater Runoff Rules and Regulations of 1990: This program is known as the National Pollutant Discharge

Elimination System (NPDES) which was amended by Congress in the CWA of 1987. The amendment required EPA to establish phased NPDES requirements for storm water discharges. To implement these requirements, EPA published the initial permit application requirements for certain categories of storm water discharges associated with industrial activity, and discharges from municipal separate storm sewer systems located in municipalities with a population of 100,000 or more.

3. The Pollution Prevention Act of 1990: The pollution Prevention Act identifies pollution prevention as EPA's environmental management approach of choice, and requires the incorporation of pollution prevention into EPA activities beginning in the Federal Fiscal Year (FFY) 1994 State/territory grants cycle.

4. The Coastal Zone Act Reauthorization Amendment of 1990: This amendment was intended to strengthen the links between Federal and State coastal zone management and water quality programs and enhance State/Territory and local efforts to manage land use activities that degrade coastal waters and coastal habitat. States/Territories with approved coastal management programs are required to develop Coastal Nonpoint Pollution Control Programs. The programs must be submitted to EPA and NOAA for approval. The coastal nonpoint pollution control programs will be implemented through both State coastal zone management programs and State NPS management programs.

5. The Federal Intermodal Surface Transportation Efficiency Act of 1991: The Federal Intermodal Surface Transporation Efficiency Act (ISTEA), established the Surface Transporation Program (STP). ISTEA also created a transportation enhancement activities program as a component of STP. Ten percent (10%) of the funds apportioned to a state for the STP is only available for these enhancement activities. Eligible transportation enhancement activities consist of the following:

* Provision of facilities for pedestrians and bicycles

* Acquisition of scenic easements and scenic or historic sites

* Scenic or historic highway programs

* Landscaping and other scenic beautification

* Historic preservation

* Rehabilitation and operation of historic transportation buildings, structures or facilities including historic railroad facilities and canals

* Preservation of abandoned railway corridors including the conversion and use thereof for pedestrain or bicycle trails

* Control and removal of outdoor advertising

* Archaeological planning and research

* Mitigation of water pollution due to highway runoff

6. USDA 1990 Farm Bill or the Food, Agriculutre, Conservation and Trade Act of 1990: This farm programs law reinforces USDA commitment to protecting the nation's natural resources. It expands the conservation provisions under the Food Security Act of 1985. It encourages the reduction of soil erosion, the retention of wetlands and protection of other environmental sensitive cropland. The provisions include:

(a) Conservation Compliance: Discourages the production of crops on Highly Erodible Lands (HEL) cropland unless the land is protected from erosion under an approved conservation plan or system. The plan or system must be fully implemented by December 31, 1994.

(b) Sodbuster: Discourages the production of crops on HEL lands that was not used for crop production between 1981 - 1985 unless the land is protected from erosion under an approved plan or system. The plan or systems must be fully implemented before crops can be planted on the HEL land.

(c) Swampbuster: Discourages the alteration of wetlands for agricultural purposes.

(d) Conservation Reserve Program: Offers long-term rental payments and cost-share assistance to farm owners or operators to establish permanent vegetative cover for land that is HEL or contributing to a serious water quality problem.

(e) Wetlands Reserve Program: A voluntary USDA easement program to restore and protect wetlands.

7. The Clean Vessel Act of 1992: Although this is not a NPS federal law, it is a Federal law that you may want to become familiar with. This law allows States to apply to the U.S. Fish and Wildlife Service for grant funds to construct pump out stations and waste reception facilities. A total of 12.5 million was made available during the first open period ending on August 31, 1993.

SAFEGUARDING OUR FUTURE RESOURCES

LaVerne E. Ragster

Eastern Caribbean Center, University of the Virgin Islands
St. Thomas, US Virgin Islands 00802

There is a growing school of thought that says there will be poor, or no prospects for the future of humanity and the world's natural resources if individuals, communities, and governments do not quickly begin to recognize that conservation and development are essential parts of one indispensable process. This would mean the challenge implied in the title of this talk is the need to change (where necessary) attitudes and behaviors of people at all levels of organization. This change is necessary to realize development that concentrates in an integrated fashion on improving the human condition and maintaining the diversity and productivity of nature. *Caring for the Earth* (7) describes a strategy or guide for achieving sustainable societies and proposes this solution as *the* rational option open to humanity.

The nine principles proposed for a sustainable society are not new to some cultures of the world, but they would require significant changes in the behavior of people and institutions in most societies today. The principles are based on the need for cooperation and caring among people, on the acknowledgment of limits in nature, and on an ethic that recognizes nature has to be cared for in its own right, not just as a means of satisfying human needs. The deliberations that will occur at this conference run the risk of being self-serving to a small part of society - the converted speaking to the converted for reassurance. It would also miss an opportunity to move the US Virgin Islands ahead in its quest for a rational future, if the principles listed below (or some other similar conceptual guide) are not used as benchmarks for a code of belief and proposed actions.

A World Conservation Strategy
Principles of a Sustainable Society (7)

1. Respect and care for the community of life.
2. Improve the quality of human life.
3. Conserve the Earth's vitality and diversity.
4. Minimize the depletion of non-renewable resources.
5. Keep within the Earth's carrying capacity.
6. Change personal attitudes and practices.
7. Enable communities to care for their own environments.
8. Provide a national framework for integrating development and conservation.
9. Create a global alliance.

The aforementioned principles imply that the existence and good health of future natural resources of the Virgin Islands require present-day efforts to focus on dialogs and actions which result in the Virgin Islands community living sustainably. Clearly, this is no small challenge for an urbanized, multi-cultural political dependency with a small land mass, a high population density, mass tourism as the main economic activity, and limited, vulnerable natural resources. The USVI has begun to address the changes necessary to view and implement development and conservation as part of the same process, but like most of the rest of the world, we have much to do to make discussions and small initiatives toward sustainable development grow into a way of life.

It is useful at this point to share two versions of the definition of sustainable development.

Sustainable development is:

a) improving the quality of human life while living within the carrying capacity of supporting ecosystems (7); and it also is

b) a process in which qualitative development is maintained and prolonged while quantitative growth in the scale of economy becomes increasingly constrained by the capacity of the ecosystem to perform over the long run two essential functions: to generate the raw material inputs and to absorb the waste outputs of the human economy (2).

It follows from these definitions that a sustainable economy becomes the product of sustainable development. Then, it is logical that a sustainable economy must maintain its natural resource base and continue to develop by adapting and improving using knowledge, organization, technical efficiency and wisdom. Therefore, one of the challenges to the realization of a sustainable economy is the increasing levels of pollution (in the world) which impact human and environmental health in a negative manner. In the waters surrounding the Caribbean archipelago, wastes produced continuously and often imperceptibly by land-based activities, contaminate and adversely impact marine ecosystems (and the health of marine resource users). The most evident sources of this nonpoint pollution in the region include (14): agriculture and forestry; construction works; urban run-off; atmospheric fall-out; ground water seepage; oil and other chemical spills and disposal; solid-waste disposal and its leachates; sub-surface disposal of sewage and other wastes; and mining operations.

Today we live in a world where some economists argue that pollution control involves establishing a balance between the use of the environment for waste disposal and its use for all other purposes (5). The conflicts that often result among the different parties concerned with pollution of an area or resource have helped to foster the development of policies and mechanisms (from a number of conceptual frameworks - mostly rooted in economic theory) for conflict resolution and prevention of pollution. The USVI has benefited from this ongoing process. However, there is still a need to customize mechanisms for prevention and control. Therefore, the formulation and implementation of policy on pollution prevention and control appropriate for the USVI would be assisted by considering some of the questions that pertain to 'safeguarding future resources' within the context of achieving sustainable development in the territory.

The determination of the types and levels of resources that should be protected for the future is tied to the environmental ethic we accept and practice. The list of natural resources (including habitats) we believe should be protected or conserved would probably be most diverse and most numerous if we agreed that all natural resources have intrinsic value. On the other hand, if other organisms have no rights to life and their "purpose" on the planet is to be fully exploited for human derived benefits, we are likely to have low numbers and kinds of resources available.

The natural resources in the USVI that are viewed as having high value, as is the case in much of the Caribbean region, include marine ecosystems - coral reefs and seagrass beds; coastal ecosystems - mangrove forests and lagoons and salt ponds; and terrestrial ecosystems - dry to moist evergreen and rain forests, especially those associated with watersheds. (Refer to Table 1.) The value of these resources as habitats, as food and raw materials sources, as structural protection and as contributors to the quality of life continues to be demonstrated and studied. The question is whether we want to pass on some, all, or none of these resources and their value to future generations.

Another part of the question relates to the condition or health of the resources that are available to future societies. Ecosystems found in the

Virgin Islands and other Caribbean islands are usually connected to each other and surrounding human built systems through the movement of water, air and organisms. (Refer to Figure 1.) Hence, pollutants and disease vectors can move with energy and materials between systems in an opportunistic manner, to the detriment of the physical and biological capacity and diversity of the impacted areas. This situation presents a major challenge to management of these areas and the control of pollution, especially with regard to nonpoint sources of pollution. Consequently, an exploration of "safeguarding of resources" must address current activities of human societies and their potential to influence the health and stability of natural resources.

The question of who is to be responsible for the type and level of societal impact on natural resources is one that has received international attention. An increasingly popular position is that a sustainable society will depend on new partnerships of local people, citizens' groups, businesses and governments. In this case, it is essential to have early substantive input by partners into development plans which strive to be equitable, sustainable, practical, sensitive to local norms and cultures, and are welcome to the people concerned. The implication here is that everyone has a stake and an opportunity in the process of addressing the management and conservation of natural resources. Clearly, there would be a need for information on the resource and its current or potential uses and users, open dialog between partners, and new roles in research, monitoring and management for various partners. The skills needed to undertake the group dynamics associated with multi-disciplinary teams and innovative problem-solving will have to be crucial elements of the training of citizens, politicians, urban and rural managers, as well as of educators and other professionals. Therefore, the answer to who will safeguard our future resources should be everyone who could possibly help - all of us.

Suggestions and recommendations concerning steps that should be taken to move Caribbean societies toward sustainable living have come from many individuals and groups, including many at the regional and international levels. The nine principles of the World Conservation Strategy (1980) developed by the United Nations Environment Programme (UNEP), The World Conservation Union (IUCN), and World Wildlife Fund (WWF), have already been mentioned, and are mirrored in the outputs of the United Nations Conference on Environment and Development (UNCED) - Agenda 21, the Biodiversity Convention, the Framework Convention for Climate Change, and the Declaration of Principles on Forests. Within the region, the Port of Spain Accord on the Management and Conservation of the Caribbean Environment (1989), The Caribbean Action Plan of the Caribbean Environment Programme (1981) and the Report of the West Indian Commission - Time For Action (1992), have all presented concerns and strategies related to the implementation of sustainable development in the region.

Generally, the following approaches (modified from the Port of Spain Accord) are included in strategies proposed as appropriate ways to address present development challenges and the achievement of sustainable societies.

a) Provision of training and the development of human Resources to produce appropriately trained professionals and experts as well as an informed and active citizenry.

b) Collection, management and dissemination of information required for policy formulation and decision-making within the conceptual framework of sustainable development.

c) Formulation of policies and plans that integrate economic, social and environmental issues through the use of interdisciplinary teams at all levels.

d) Development of legal frameworks and institutional arrangements which facilitate environmental management and rational development.

e) Promotion of economic pursuits which acknowledge and respond to environmental parameters and limits.

f) Inclusion and harnessing all available political, institutional and community-based resources in the process of development and problem-solving for society.

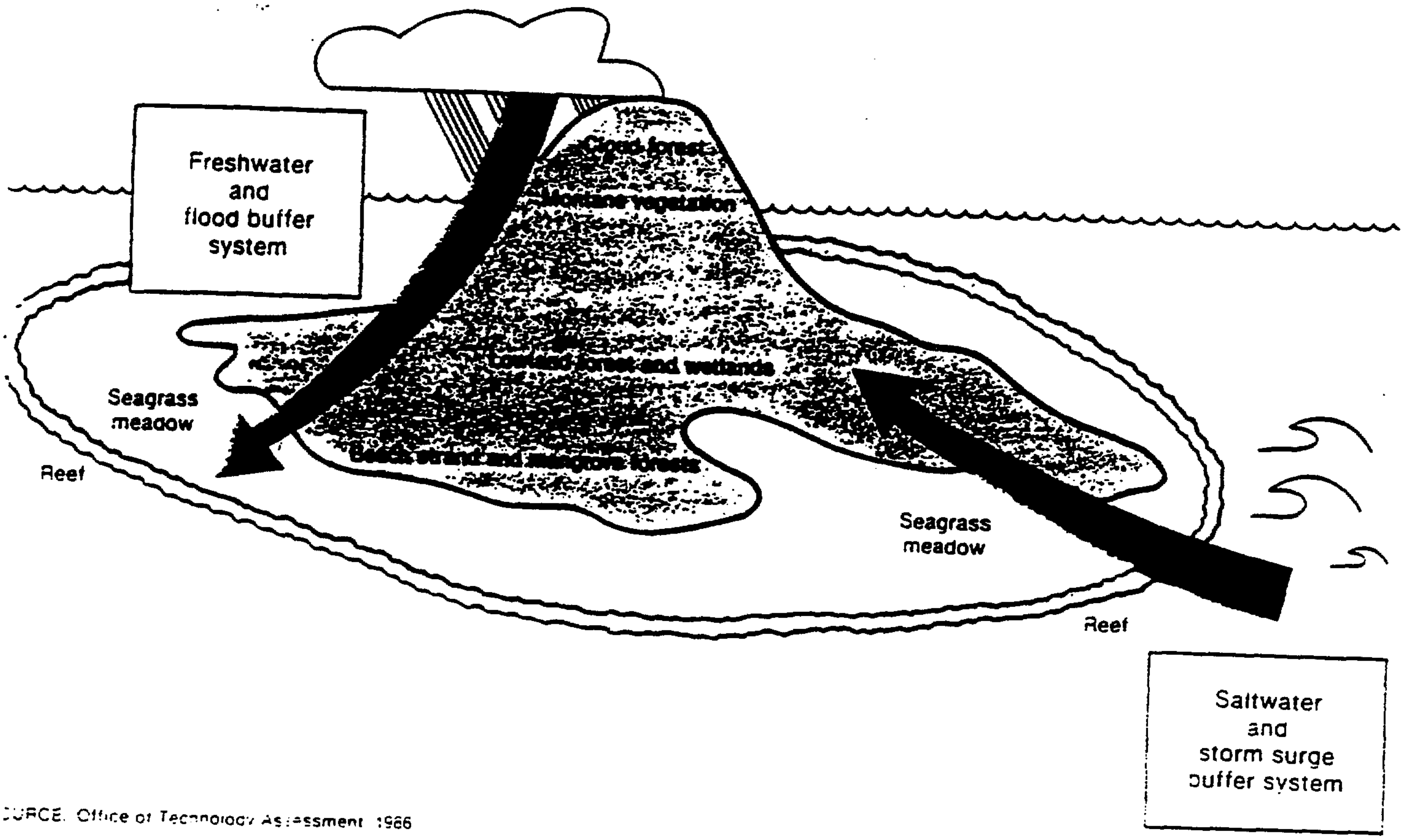
Locally, the Comprehensive Water and Land Use Plan , the development of 18 Areas of Particular Concern under the Coastal Zone Management Program, and legislation related to endangered species and the Territorial Park System identify and begin to shape the Virgin Islands' vision of living sustainably. When the discussions at the local and regional levels concentrate on pollution as an issue, the specific recommendations for a strategy include a) pollution prevention methods, b) effluent limitations; c) water quality limitations; d) environmental planning; and e) the use of best management practices (6).

Clearly, there are gaps and areas of weakness that must be confronted if reality in the future is to match the vision of the territory and the region. Three major concerns are the establishment of policies and groups of people and/or institutions which will facilitate 1) the integration of economic, social and environmental planning within a framework that specifically addresses sustainability; 2) the development of mechanisms which will more effectively incorporate various interests of Virgin Islands society into planning and management associated with development; and 3) the formulation of education and awareness programs (formal and informal) that would provide everyone with the appropriate conceptual framework and the problem-solving and group dynamic skills needed to individually construct and implement a sustainable lifestyle. Implementation of strategies to address these concerns, challenges governments and institutions in the Virgin Islands and the region to significantly adjust institutional attitudes and arrangements as well as the way funds are currently directed.

A reminder is perhaps appropriate at this point. We humans have a difficult time accepting and implementing change, especially the far-reaching type proposed in the concepts of sustainable development. The recommendations made require all of us to re-examine our values and alter our behavior - at the individual and institutional levels. Hence, any negative (physical or mental) responses you may experience in reaction to ideas mentioned concerning sustainable living may be signs of personal discomfort with the idea of change. It is my sincere hope that over time the dissemination of information and guidance through formal and informal education activities, as well as incentives from society to make changes in how we address development, will move us to formulate and implement the policies and systems needed for the survival of our natural resources, ourselves and our society.

How we handle nonpoint pollution today will be one of the determinants of whether the next generations of Virgin Islanders have thriving coral reefs, watersheds with clean ground water, healthy versions of Magens Bay and Trunk Bay, populated seagrass beds in the inshore waters of St. Croix and a functional mangrove lagoon on St. Thomas to manage and enjoy. The challenge to us concerning the safeguarding of future resources must be confronted within the context of resolving our development and quality of life issues as we strive to achieve a sustainable society.

Figure 1 —Erosive Energy Buffer Systems on Islands



SOURCE: Office of Technology Assessment, 1986

Table 1 —Ecosystems Present on the U.S.-Affiliated Islands

d Areas	Puerto Rico	USVI	American Samoa	Guam	CNMI
d forest	Present on mountain tops	May have been present on mountain tops	Undisturbed formation on top of Ta'u	Possibly on top of Mount Lamlam	Mount Tapacnau, Saipan; other islands unknown
montane rain-it	Formerly on higher mountains	None	Midelevation ridges and as secondary growth	None	None
and rainforest	Little remains	None	Remains on steep slopes	Scattered remains of limestone, species-rich forest	Lava forest on northern island
rine and swamp it	Limited extent remains	None	Limited amount present along streams	Present along rivers, moist ravines; mostly in south	In ravines on smaller islands
ropical moist/ onal forest	Little remains	Limited areas in mountains or remote areas	None	None	None
ropical dry it	Present, little of original ecosystem	Present, considerably reduced from original extent	None	None	None
nna and slands	Considerable man-made areas maintained as pasture or ground cover	Present in former agricultural areas	Present as early sere after disturbance	Extensive fire-adapted areas in south	Extensive natural formation in northern islands, man-made on Saipan and others
b	Present, often as secondary growth	Present	Present on on Matafao and Piao mountains, Tutuila	On rocky limestone coast and some southern areas	Coastal volcanic rock in north and limestone coast in south
lands	Some rivers, and marshes, and some saltwater marshes occur behind mangroves	Saltwater ponds in bays behind mangroves	Streams and coastal marshes; lakes on Ta'u and Anu'u	Some streams and rivers; reed swamps; saltwater and freshwater marshes; man-made lake	Saltwater and freshwater marshes, freshwater lakes on Saipan and Pagan, brackish on Pagan
grove forest	25 mi² scattered around coast	Forests only on St. Thomas and St. Croix	Pala lagoon (stressed) on Tutuila, and on Aunu'u	Small areas, particularly Apra Habor	Limited areas in southern islands
l/beach forest scrub	Present in some areas	Present	Widespread, special types on Rose Atoll and Swain's Island	Common, includes some endemics	Present on some of the southern islands
oons/shallow oms	Behind barrier reefs and other offshore features	Extensive in bays, inside reef and along shelf	Lagoons on Rose Atoll, Swain's Island and Tutuila	Cocos lagoon	Shallow lagoon inside some reefs on Saipan and Tinian
al reefs	Barrier, fringing and patch reef areas most damaged	Bank barrier reef and algal ridge; also fringing barrier and patch reef complexes; some damaged	Main islands largely bordered by fringing reefs; some damaged	Barrier reef near Cocos island, variety of patch and fringing reefs elsewhere, some damaged	Fringing reefs common in southern islands, some damaged

RCE: A. L. Dahl, "Tropical Island Ecosystems and Protection Technologies To Sustain Renewable Resources in the U.S.-Affiliated Islands," OTA commissioned paper, Washington, DC, 1986.

Table 1.—Ecosystems Present on the U.S.-Affiliated Islands—Continued

		Federated States of Micronesia			
Marshalls	Palau	Kosrae	Ponnpei	Yap	Truk
None	None	Present on mountain top	At highest elevations	None	None
None	None	At midelevations, some disturbed	At midelevations	None	Limited area on top of one volcanic mountain
None	Limestone, species-rich	Present with many endemics, nearly undisturbed	Present, most areas disturbed	Species-rich forests, most are disturbed or replaced	Present, disturbed
None	Along rivers and inland of mangroves	Along rivers and inland of mangroves	Dense along rivers, inland of mangroves	Present, inland of mangroves	Present, inland of mangroves
None	None	None	None	None	None
None	None	None	None	None	None
On smaller islets of some atolls	Present on clay soils, and where fire-maintained	Present	Present often from burning	Now predominant on clay soils, or where frequently burned	Present
Some on northern islands	Outer edges of limestone forest, rocky coasts and strip mined areas	Present	On rocky coasts and some ravines	Present in some degraded areas	Present
Freshwater pond on Lib; tidal saltwater marshes	Streams, rivers, lakes, ponds, swamps, freshwater and saltwater marshes	Short streams, and other freshwater habitat	Streams, rivers, lakes, ponds, swamps, and marshes	Freshwater streams, ponds, swamps, and marshes	Low swamps and marshes
In depressions on a few atolls	"1,313 acres in estuaries and along coasts of archipelago	3,859 acres around island	"3,562 acres along coast and estuaries, some on Pingelap Atoll	2,894 acres on Yap, and some on Elato and Woleai Atolls	3,315 acres around main islands
Largely replaced by coconut and breadfruit, except on some northern atolls	In a few areas behind beaches and on Kayangel Atoll	Present behind beaches	On high islands, largely replaced by planted trees	On atolls and behind beaches, often replaced by coconut	On atolls, islets; and in some coast areas
Large open lagoons, closed lagoon in Namonk	Lagoons within barrier reef, also Kayangel Atoll and Helen Reef	Some shallow lagoons inside reef	Extensive lagoon with seagrasses, and atoll lagoons	Some shallow lagoons within reef and atoll lagoons	Over 2,000 mi² including atoll lagoons
Islands built by coral reef ecosystems, some damaged	Barrier, fringing and patch reefs; rich and diverse; also some atolls; some areas damaged	Largely surrounded by fringing reef	Extensive barrier reef enclosing lagoon with fringing and patch reefs, and outer atoll islands	Wide, fringing reefs, outer atoll islands	Major barrier reef with islet enclosing lagoon with complex structures, outer atoll islands; considerable damage

1993 NPS Pollution Conference

HAVE YOU THOUGHT ABOUT THIS?!!

1. WHICH OF THE FOLLOWING STATEMENTS MOST CLOSELY MATCHES YOUR POSITION OR PHILOSOPHY? Circle the letter of your choice.

A. Future generations should not expect development activities of today to consider their needs.

B. Substitution of resources and technology will provide the answer to concerns about the loss of habitats and biodiversity to future generations.

C. Humans are the only organisms with a right to access and exploit the Earth's resources.

D. When, despite technological assistance, the capacity of a natural system is overcome by waste and byproducts of human society, humanity will find other resources to meet its needs.

E. The loss of most resources only have a limited negative impact on the planet's natural systems, and in the long-term these losses will not matter to the survival of human-built systems.

F. None of the Above.

2 What resources do you see as being necessary for the future of the Virgin Islands?

3. Who should be responsible for efforts to sustain long-term levels and the health of the Virgin Islands' resources?

4. If your position or philosophy was not included in number 1 on this sheet, please indicate it below in one sentence.

5. Which of the following is the most important for obtaining a development approach that provides future generations with the highest number of options regarding development and quality of life.

a) Financial resources
b) Technology investment
c) Economic reform
d) Directed research and monitoring
e) Institutional reform (private and public)
f) Educational reform
g) All of the above
h) None of the above

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RESPONSIBLE ECOTOURISM DEVELOPMENT

Stanley Selengut

MAHO BAY CAMPS, INC.

Ecotourism, a relatively new idea in the travel industry, is an outgrowth of the increasing awareness that environmental responsibility is a global concern. The ecotourist seeks destinations that reflect this widening international ethic. The new breed of traveler tends to be well educated, adventurous and skeptical. An ecotourism resort that offers only environmental window-dressing will not survive the scrutiny of such an ecologically sensitive clientele.

My experience as builder, owner and operator of Maho Bay Camps convinces me of this. When I first opened for business 17 years ago, the environmental movement was just beginning to stir and the term ecotourism did not exist. My original intent was simply to offer an inexpensive vacation that was close to nature but provided a degree of comfort and convenience not found in a traditional campground.

The Maho Bay site presented a unique opportunity. Its 14 acres are located within the U.S. Virgin Islands National Park on St. John. The hillside setting overlooks one of the Caribbean's most beautiful beaches, one of the many that scallop the island's north coastline.

Since the land I leased was an erosion-prone hillside, site disturbance was to be avoided. With New York architect Jim Hadley, I designed a community of three-room "tent cottages" set on platforms cantilevered on the hillside. The 114 units are arranged in clusters. To further minimize site disturbances, the clusters are connected by raised walkways joined by stairs. Guests can reach virtually any part of Maho without ever disturbing the ground cover. Bathhouses, containing toilets, sinks and showers are located in various sections of the grounds.

Construction techniques at Maho restricted the need to clear trees and vegetation. Footings for the posts that support all the elevated walkways and platforms were dug by hand. When completed the tent-cottages appeared to have been built in the trees that grew on slopes. Each tent-cottage is furnished with beds, chairs, a table and bottled-gas cooking stove. Occupants have unobstructed views of sea and distant islands while the units are scarcely visible to boats cruising off the beach.

The inconspicuous infrastructure of Maho was also designed for low environmental impact. Electrical cables and water

pipes were attached to the undersides of the walkways, eliminating
the need to dig trenches. Pull-chain showers and low-flush toilets reduced fresh water use in the bathhouses. A centrally located aluminum-can compactor increased the efficiency of the our recycling program. The profusion of native trees, plants and flowers thrive on "gray water" that is recycled from our treatment facility and distributed through an irrigation system. Birds, bats, lizards and tree frogs flourish under these conditions and keep insect populations in check while providing entertainment for the guests. Nature can be a rewarding stage, if only we keep our props and directions from altering the original script.

Maho also has two large pavilions where guests can gather to see films, attend lectures by Park rangers and visiting wildlife experts, hear live music or eat at our self-serve restaurant which offers fresh vegetables, fish and a variety of foods from a health-conscious menu. Since eating is a universally understood cross-cultural experience, many of Maho's dishes are prepared from local island recipes.

Educating by example is central to the Maho concept. The more I learn about getting the most from nature with the least environmental cost, the more I want to expand the example. I am currently building a research/resort adjacent to the Maho campground. It is called Harmony and is designed to take ecotourism to its next logical level: a resort dedicated to the principles of sustainable development. Environmental scientists and government agencies define this concept in varying ways. Basically, sustainable development is the practice of using natural resources no faster than they can be regenerated. In short, Do Not Kill the Goose That Lays Golden Eggs.

Harmony will be a small community built from recycled materials. Wood scraps, plastic bottles, crushed glass and ground tires are now the "raw materials" for sustainable-development construction products. The living spaces are designed to maximize comfort with the least amount of energy. Harmony will run "off the grid." All electricity will be generated by sun and wind, using solar panels, a windmill and storage cells. Each unit will also contain a computer so that guests can monitor and adjust their energy use according to prevailing conditions.

Most of the planning for Harmony comes from discussions and workshops with environmentalists, engineers and administrators from the U.S. National Park Service and the U.S. Virgin Islands Energy Office. Sandia Laboratories of Albuquerque, N.M. is providing know how and experimental hardware, such as a solar powered ice machine. In a real sense, Harmony is a proving ground for the latest sustainable development ideas and technology. Practical data, including input from guests, will be fed back to Sandia and environmental agencies. The resort will also function as an educational facility, attracting specialist and school children alike.

The goal of Harmony is to demonstrate that an ecotourism facility can balance both nature and culture -- can, in fact, be mutually enhancing. If my experience in the field has taught me anything, it is that we are not separate from but part of our ecosystem, and with that privilege comes the responsibility to nurture it.

II
URBAN SOURCES OF NONPOINT POLLUTION (LAND USE PLANNING AND CONSTRUCTION)

** Paper not available at time of printing.*

EFFECTS OF EROSION ON TERRESTRIAL AND MARINE ECOSYSTEMS

Ralf H. Boulon, Jr.

Division of Fish and Wildlife, Dept.of Planning and Natural Resources, 6291 Estate Nazareth 101, St. Thomas, V.I. 00802-1104

As most of us are very aware, the Virgin Islands are a beautiful and relatively healthy place to live. We have clean air, clear water and examples of nearly every tropical ecosystem found in the western Atlantic region.

However, all is not well. Our natural systems, while still relatively healthy and productive, are gradually losing the fight against man's activities. This paper will discuss our major natural ecosystems in terms of their value to us and to each other, what is happening to them due to development induced erosion in particular and what it means to us and our quality of life here in the Virgin Islands. Development as discussed in this paper can range from a single family residence to a major hotel.

Erosion can be defined as the disturbance or destabilization of soils or marine sediments which enables them to be moved from their point of origin by external factors such as rain, waves or currents and which can result in a detrimental effect on natural living systems. Disturbance or destabilization results from any activity which removes vegetation and/or penetrates the soil or sediment surface. The steep slopes found in the Virgin Islands greatly increase the propensity for erosion and significant soil loss.

While many aspects of development have detrimental effects on our environment, this paper will be limited primarily to the effects of erosion on our natural systems. The major natural systems that will be discussed in this paper include terrestrial forests, saltponds, beaches, mangroves, seagrass beds, coral reefs and algal plains.

Terrestrial forests - We have a variety of terrestrial forests here in the VI. Many species of birds and animals live in them, they make oxygen for the air we breath, they provide food for us and animals, they make our soil, and they hold the soil where it belongs with their roots.

Through development, both residential and commercial, we have bit by bit lost considerable amounts of our terrestrial forests which has led to erosion and sediment washing into the ocean where it has affected mangroves, seagrass beds and our coral reefs. This loss of topsoil has led to changes in the types of forest capable of being supported by our land. Thinner soils cannot support as large trees nor can it hold the moisture necessary for the growth of many of our indigenous tree species.

Many of our guts contain rock pools that support a variety of freshwater fish and shrimp species. The sediment produced by erosion clouds the water and kills these animals. We have probably already lost most of this small but important ecosystem to development.

Through proper sediment control practices and rapid replanting, much of this soil loss can be controlled and reduced to tolerable levels for our coastal and marine systems. Another related problem is that of septic tank effluent and nutrient loading in our soils. The creation of shallow soils through erosion reduces the capacity of the soil to absorb the effluent. This enriches rain runoff and may cause eutrophication of our nearshore waters which affects all of our marine communities. Septic systems utilizing leach fields should not be allowed under certain soil types and conditions.

Saltponds - Saltponds provide food (crabs, shrimp) for many species of birds. They are also the front line defense in trapping soil that escapes from the hillsides which can smother our corals, seagrasses and fish. In fact, most of our upland watersheds end in saltponds which trap sediment in runoff through settling action and filtration through the berm which separates the pond from the sea. Under natural conditions, the filling of a saltpond with upland soils takes many thousands of years, about the same rate as which new saltponds are formed.

Historically, saltponds have been viewed as smelly areas good for either filling in to build on top of or dredging for marinas. Either scenario destroys wildlife habitat and causes many tons of sediment to reach our ocean waters.

As upland sources of sediment erosion have increased we are finding that our saltponds are filling in with this sediment at a rate far exceeding the natural one. As this happens, the salt ponds lose much of their retention capability and more sediment ends up reaching the sea. As the ponds fill in with sediment, conditions become favorable for successional colonization by wetland and terrestrial vegetation and the size of the ponds is further diminished. Over time, our ponds may become filled in before new ones are created and nearshore marine communities will become smothered with sediments and die. We need to explore ways in which natural sediment reduction systems can be enhanced, supplemented or even replaced by man-made systems. This may become absolutely necessary if we are going to save our nearshore marine ecosystems.

Beaches - Our shorelines contain a variety of beaches, from small pocket coves to long open beaches. They serve as filters for rain runoff, nesting habitat for turtles and some birds, and critical habitat for many species of crabs and other invertebrates. Our economy also depends on beaches for many of our tourism dollars.

Development here has certainly affected many, if not all of our beaches in one way or another. A number of beaches have been seriously altered through sand mining activities and erosion due to coastal modifications such as rock groins. Increased wave erosion after destruction of the offshore protective reefs during dredging activities has also caused beaches to all but disappear.

Increases in terrestrial soils and organic matter from upland erosion and runoff can lead to increased vegetative colonization of our beaches. More soil in the sand permits more plants to grow. As more vegetation grows on our beaches, it reduces the available habitat for turtles and seabirds to nest. It also leads to increased root growth and makes it harder for turtles to dig and hatchlings to survive.

Placing of sand on beaches as a beach creation project or renourishment program can be devastating to nearby marine ecosystems if the sand being placed on the beach is of a smaller grain size than what was originally there. All beaches are in a state of natural equilibrium with the wave and energy environment at that beach. Placing of finer sands on the beach will result in the waves removing it from the beach and depositing it on other nearshore marine ecosystems. Any project of this nature must have grain size and composition analyses done prior to selecting a source of sand for the project. Another mistake is when someone wants to create a beach where there was no beach before. The reason no beach was there before is that the energy environment will not allow one to accrete there. Any attempt will be met with disaster, both for the developer as well as for the nearby marine ecosystems.

Mangroves - Many of our deeper bays and larger watersheds end in mangrove stands. These mangroves filter sediments and chemicals from rain runoff, stabilize our shorelines, provide nesting habitat for many species of birds, and provide nursery habitat for juvenile fish where they grow up in the submerged roots. Mangroves are also a source of carbon based nutrients for other nearshore ecosystems.

Mangroves are another habitat that many feel are much better suited for cutting, filling and building on. But, in fact, they are a habitat whose importance touches most of our lives. We estimate that we have lost approximately 50 percent of our mangroves here in the Virgin Islands to development activities during the last 40 years. Most of this has resulted from large scale destruction such as Krause Lagoon on St. Croix or the Mangrove Lagoon on St. Thomas. Not as obvious, but also significant, the cutting of several trees here and there for such things as docks has eliminated much of our mangroves. And we have paid the price. Fishermen in St. Croix tell us that fishing declined significantly after Krause Lagoon was destroyed. Nearshore reefs in southwestern St. Croix have been overwhelmed with sediment and have all but died. Species of wildlife that depend on mangroves for nesting habitat where they can be safe from predators have to deal with less safe areas to nest in, and as a consequence, their populations decline.

The increases in upland erosion have led to changes in the hydrodynamics and soil conditions necessary for mangrove health and survival. As more soils are deposited over mangrove areas, soil salinity and moisture decreases and the vegetation changes to more terrestrial species. Species of crabs that depend on the saturated soil for refuge and the birds that depend on the crabs for food likewise suffer for the worse. Sediments in the water clog the gills of juvenile fish and invertebrates, causing them to die or leave. The increase in nutrients from the soils causes algal blooms which reduces available habitat for fish. The result is the elimination of the nursery value of the mangroves and consequently, the reduction of fish in nearby marine ecosystems.

Our mangroves are now protected by law and cutting or damaging them is illegal. Mangroves can be successfully replanted in areas where they have been removed as long as environmental conditions necessary for their growth have been restored. However, it is very hard, if not impossible, to establish a viable mangrove ecosystem in an area where they have never been.

<u>Seagrass beds</u> - Many of our coastal bays are carpeted with seagrass beds, the marine equivalent of a lawn. Much as a lawn will keep soil from eroding during rain, these seagrasses stabilize the sea bottom during periods of high waves or strong currents. They are important foraging areas for turtles, conch and urchins, and are nursery habitat for many juvenile fish, lobsters and other animals. Calcareous algae from seagrass beds is the major component in beach sand here in the VI. Recovery from damage to a seagrass bed may take decades.

The major threat to seagrass beds here in the VI has been from dredging in the past for sand, either for construction or to fill saltponds on which to build developments or for channel widening or deepening. With very limited exceptions, dredging should no be longer permitted in the VI due to the serious effects it has on all marine ecosysytems. Replanting of seagrasses is a costly and time intensive project but can be done with some success.

Upland erosion of soils and the introduction of these sediments into our marine waters has subtle but serious long-term consequences for our seagrass beds. This sediment reduces water clarity which diminishes the amount of sunlight penetrating the water. Seagrasses require sunlight to photosynthesize and a decrease in light penetration causes seagrasses in deeper areas to die off. This destabilizes the seabed which leads to greater suspended sediment and a further decrease in water clarity, thus increasing the problem. This naturally then has a trickle-down effect on all other marine ecosystems.

__Coral reefs__ - We have considerable amounts of coral reef habitat here in the VI, from nearshore fringing reefs to offshore bank and shelf edge reefs. They are very important in protecting our shorelines from wave erosion. And, like a tropical rainforest in their diversity, thousands of species of fish, plants and invertebrates live in coral reefs, many of which are eaten by man. Coral reefs are also an important source of beach sand and are vitally important to our tourist based economy.

Development has taken a serious toll on our reefs. Sediment and nutrient runoff from land as well as past dredging activities has caused a serious decline in health of our reefs. In fact, several noted marine scientists have determined that Puerto Rico has lost nearly 100 percent of its nearshore coral reefs over the past 50 or 60 years due to sedimentation from upland erosion.

Reefs require a very narrow set of environmental conditions to grow and maintain their health. Sediment in the water smothers the coral polyps and restricts feeding and photosynthetic activity necessary for their survival. Without a reversal in water quality trends and increased effort to restore the natural balance I fear that we will see a gradual decline and eventual loss of our once productive reef areas. Establishment of marine reserve areas with anchoring and harvest restrictions for marine species can provide significant protection to key examples of our marine ecosystems. These can also potentially create areas that provide a source of recruitment of marine organisms including fish and corals to nearby non-protected areas.

__Algal plains__ - A habitat that few people are even aware of is the algal plain. These are deep water areas with high algal diversity that cover extensive portions of our insular shelves. They may be important juvenile habitat for some species of fish (Queen Triggerfish) and lobster.

To our knowledge, development has had little to no direct affect on algal plains but, as the overall health of nearshore habitats and water quality declines, the delicate balance of our algal plains can't help but be threatened as well.

Of course there are countless other ways in which erosion is affecting our natural systems, many of which we are probably unaware of.

__Conclusion__ - One very important concept that needs to be remembered is that all of these animals, plants and ecosystems, both terrestrial and marine, interact with each other and are interdependent on each other for their health and their very existence. No one ecosystem or animal should be considered all by itself. Each one depends on the others for such things as energy flow, maintenance of water quality, nutrients, shelter, etc. But this only works if the systems are in balance. Any disruption in the interactions between animals, plants and ecosystems can throw the whole process out of balance.

Through effort and careful planning, we can save, protect and enhance what we have left and possibly recover some of what we have lost. The control of erosion and the resultant sedimentation should be one our top goals. The effects of erosion will lead to the loss of most if not all of our nearshore marine ecosystems. Sediment control practices must be instituted whereever the soil is to be disturbed. These sediment control practices must be enforced and monitored if they are going to be effective. Replanting of disturbed soils must be done as soon as possible to reduce the chances of soil loss. Projects requiring major soil disturbance should also be timed to coincide with periods of least rainfall where possible and practical.

We must all endeavor to learn more about and try to understand the problems that are facing our environment and ourselves. For the more we understand, the greater will be our ability to make the right decisions to solve those problems.

WHAT YOU CAN DO TO MINIMIZE OR PREVENT EROSION

Victor Giraud

Department of Planning and Natural Resources, St. Thomas, U. S. Virgin Islands

A major problem faces us here in the Virgin Islands. A problem, I would dare say, is as serious as a heart attack. That problem is soil erosion. A heart attack is normally a final result of an ongoing disorder. Just as we change our diets when we have been told that we have a heart condition is the same reaction we need to take when we are told that our bad construction habits are the direct result of soil erosion. Otherwise, the final result will be a fatal heart attack or a damaged ecosystem whenever the problems leading up to destruction go unchecked.

Soil erosion is caused by the wind, rain, surface runoff of storm waters, and by man, who just happens to be the greatest offender. The word erosion includes all of the processes by which soil or rock material is loosened and removed, and then transported.

The energy of raindrops displaces soil particles from unprotected or non-vegetative areas. Water running on the surface of the ground picks up these detached soil particles and carries them along as it flows towards a stream system. As the volume and velocity increase, additional particles are picked up and added to the sediment load.

Eroded soil being transported by water is termed sediment runoff. Excessive sediment runoff in the Virgin Islands is caused primarily by increased development of previously undeveloped lands on mostly steep slopes. Construction activity disturbs the soil by stripping vegetation and altering natural land forms and drainage patterns. The effects of sediment runoff are particularly noticeable in the bays and harbors adjacent to watersheds that are being developed immediately following a heavy rainfall. The greater the distance the water runs uncontrolled, the greater its erosive force and the greater the damage.

Deposition occurs as the water slows down. The coarsest and heaviest particles are transported short distances. Smaller particles stay in suspension over longer distances by rolling or bouncing along, or stay in suspension while water velocity is fairly high. Because of slow setting rates, fine silt particles remain in suspension for hours and contribute to water turbidity.

Erosion in most instances is a slow but continuous removal and transportation of top soil by the forces of nature. When assisted by man, that process is dramatically accelerated. It is estimated that 5.4 billion tons of top soil are lost every year in the United States alone.

In the absence of current statistical information, I would venture to say that in the Virgin Islands, our loss to erosion is proportionately less than that of the continental

United States. However, our problem is significant enough to merit serious territory-wide concern.

Principles Forming the Basis for an Effective Conservation Program in Land Development

1. Fit the development to the topography and soils as closely as possible. Don't cut more than you have to.

2. Save trees and other natural vegetation wherever possible. Do not clear the entire site.

3. Avoid unnecessary disturbance of the soil; confine construction activities to the least critical areas.

4. Install permanent storm drains and roads as early as possible to direct storm waters.

5. Protect denuded soils with mulch or grass where permanent protection is delayed.

6. Install permanent vegetation immediately after final grades are established.

7. Use basins to trap sediment on-site.

8. Schedule the construction operations so as to only expose that area of land at a time that can be developed in a reasonable length of time.

9. Minimize impervious areas; create lawns or gravel areas.[1]

The application of these principles to fit the particular type of development will result in a practical program of environmental protection acceptable to the industry and to the Virgin Islands Government.

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[1] Environmental Protection Handbook, V.I. Department of Conservation and Cultural Affairs and the Department of Public Works, 1976.

Conservation Practices

Many conservation practices have proven effective in avoiding or lessening damage from sediment or runoff. These include:

1. Careful land clearing and protection of desirable shade trees and other plants;
2. Proper land grading with maximum slopes;
3. Constructing retaining walls and slope stabilization structures where needed;
4. Rapidly applying permanent vegetation to critical areas following the establishment of final grades;
5. Mulching;
6. Construction of waterways, diversions, and outlets;
7. Construct sediment basins;
8. Water storage structures (Ponds and Gray water cisterns).

Methods That are Used to Minimize Erosion [2]

Depending on the type of project, slope, and soil conditioning, a combination of one or more of these methods should be utilized in an effort to control erosion and sediment runoff.

Silt Fences

A temporary sediment barrier consisting of filter fabric used to trap sediment while allowing water to flow through.

Brush Berms

Temporary sediment barriers made up of uprooted trees, brush, and grass used to trap sediment in a similar fashion to silt fences. Brush Berms are bio-degradable.

[2] Environmental Protection Handbook, V.I. Department of Conservation and Cultural Affairs and the Department of Public Works, 1976.

Sediment Basins (Ponds)

A sediment basin, or pond, is created by the construction of a barrier or dam across a drainage way, by excavating a basin, or by a combination of both to trap and store sediment and water borne debris. The trapped water is allowed to overflow through a filtering system - mainly gravel - onto undisturbed areas.

Mulching

Wood chips or cut grass spread evenly over disturbed ground to prevent direct impact by raindrops.

Level Spreader

A level spreader is a flat depression constructed at grade across a slope to slow the velocity of a concentrated runoff into a level sheet flow which is likely to cause erosion.

Vegetative Cover

Planting of grasses, vines, shrubs, and trees on exposed areas to stabilize the soil and reduce damage from sediment and runoff to downstream areas. Generally, vegetative cover is used to enhance the natural beauty of the site.

Rip Rap

A permanent erosion resistant ground cover of large loose stones installed over an area subject to erosive conditions, e.g. stream banks and drains.

Gabion Baskets

A system of wire baskets filled with rock placed strategically against cut banks to protect the cut where soil conditions or water turbulence and velocity are such where soil may erode.

Retaining Wall

Retaining walls are walls constructed of masonry, timbers, rock, etc., to assist in the stabilization of cut or fill slopes and embankments.

To control or minimize erosion, one must implement a thorough maintenance and follow-up program. A site cannot be effectively controlled without thorough, periodic checks of erosion and sediment control practices. These practices, like the ones mentioned earlier, must be maintained just as construction equipment must be maintained and materials checked and inventoried. Two examples of applying this principle would be to start a routine "end of day" check to make sure all control practices are working properly and clean after every heavy rainfall.

In most cases, however, a combination of limited grading, limited time exposure, and a judicious selection of erosion control practices and sediment-trapping facilities (like the methods described earlier) will prove to be the most practical method of controlling erosion and the associated production and transport of sediment. [3]

In other words, use a common sense approach to control erosion. Look at erosion the same way you would if you had a problem with your body; with your body being the total ecosystem with live parts. Whenever those parts are affected, your entire body becomes affected - sometimes to the point of disability or even death!

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[3] Erosion and Sediment Control on Urban Areas, Oklahoma County Conservation District and Oklahoma Conservation Commission & Soil Conservation Service.

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VEGETATIVE EROSION AND SEDIMENTATION CONTROL PRACTICES

Dale E. R. Morton

Cooperative Extension Service, University of the Virgin Islands, St. Thomas, VI 00802-9990

Soil - this is the medium in which plants grow and obtain most of their nutrients. The soils in the Virgin Islands are varied in nutrient content, pH, etc. The Virgin Islands, being hilly and small in size, easily lose soil from the land to the sea by means of erosion.

Soil erosion is the loss of soil from an area by the forces of wind and water. Sedimentation, on the other hand refers to the transport and deposit of soil particles due to erosion. Since soil is formed very slowly over many decades and can be lost overnight, it is imperative for us to do all within our means to conserve and protect this limited resource. Therefore, some type of soil conservation practice should be implemented by all.

However, one must be aware that erosion and soil formation take place all the time. It is when erosion occurs at an accelerated rate, producing large quantities of sediment that we usually express concern. The loss of soil from croplands, homesites, construction areas etc. is hazardous to marine life and costly to those who have to pay for the removal of sediments from public places.

These costs and the environmental impact of soil erosion can be greatly reduced by using vegetative control measures. Once the vegetation is established the roots hold the soil in place and the canopy of the plant protects the soil from the force of the rain and reduces the velocity of the wind. It is very important to remember to avoid leaving soil exposed for an extended period of time. When it is absolutely necessary to remove vegetation, make sure that the smallest possible area is disturbed.

There are several ways in which to use vegetation to control soil erosion - establishment of lawns, grasslands and pasture, contour farming, grass terraces and windbreaks. In selecting which option is best for a particular situation, consideration should be given to slope, soil type and maintenance and labor.

Many Virgin Islanders use grasses to make lawns. In choosing the type of grass one has to take into consideration the fertility of the soil, the availability of water, and the slope of land. Once selection is made establishment can be by seed, sprig, plugs or sod. The latter two are not very common here. To establish the lawn one can broadcast the seed and mulch the area. For further guidance to the selection of grasses for lawns, you may obtain a University of the Virgin Islands Extension Service Booklet entitled " Virgin Islands Home Lawns".

Ground covers such as Ground Orchid or Air Plant Catopsis morreniana, Oyster Plant Rhoeo bicolor, Wandering Jew Zebrina pendula, Wedelia Wedelia trilobata, are sometimes used in those areas where the slopes are too steep for the establishment of lawns. Ground covers also have to be selected based on the soil condition, the effect desired, and the availability of water. For those persons living on or near coastal areas, the Beach Morning Glory Ipomoea pes-caprae is an excellent choice to control erosion. All of these ground covers have to be dense in order to provide the best erosion and sediment control. Therefore, close planting and fertilization are recommended to hasten the thickening and to prevent the formation of gullies.

The practice of planting vegetation on the contour of hills is a practice that should be encouraged. Another vegetative practice is grass terracing. The grass Khus Khus Vetiveria zizanioides is planted on the contour in strips. As a result, the flow of water is reduced; the sediments become trapped behind it. The areas in between are then cultivated and have the advantage of better water infiltration and percolation. These practices are not commonly implemented here, but I think it is one to be advocated in agricultural areas; it would be less labor intensive compared with the rock terraces which are more commonly used in the V.I.

Another vegetative means of erosion and sedimentation control is the practice of using windbreaks. In many Caribbean islands along the coastal area there are plantings of Australian Pine Casuarina equisetifolia, as wind breaks. These reduce the force of the wind, thereby reducing erosion. These particular pine trees also drop needles and cones which cover the soil and protect it from further erosion. Hedges of Tan Tan Leucaena glauca can also be used to make windbreaks in areas further inland.

Finally, the best and easiest means to control soil erosion is by allowing areas to remain established in their natural, vegetation. These plants are usually well adapted to the area and generally thrive. They maintain a good level of erosion control by the canopy and leaf litter protecting the soil from the impact of the rain and reducing the velocity of the wind.

For further information on vegetative means of controlling soil erosion contact any of the following local offices - USDA Soil Conservation Service, Agricultural Stabilization Conservation Service, V.I. Department of Planning and Natural Resources, U.V.I Cooperative Extension Service.

STRUCTURAL SOIL EROSION AND SEDIMENT CONTROL METHODS

Werner Wernicke

Virgin Islands Water and Power Authority

A. OVERVIEW

Soil erosion is a natural process which takes place over geologic time. It has shaped the land masses. Over millenniums it wears down mountains and interacts in slow equilibrium with other natural forces. It is a natural resource which rejuvenates the fertility of the land, rivers and oceans.

Man made erosion takes place at a vastly accelerated pace counted in years, months and days. It is a resource displaced thereby becoming a pollutant. Natural ecosystems are unable to respond to the rapid change imposed on it. Man made erosion becomes highly destructive and costly both to natural and man made environments.

Erosion strips land of is fertile soil layer, it ruts roadways, natural and man made channels are filled with sediment, near shore marine environments are destroys and marine facilities are shoaled to name only a few effects.

A balance needs to exist between development and the health of our environments as well as save guarding the value of our man made facilities, our property and quality of life. Most if not all of us have witnessed the destruction brought by the floods over the past two decades here in the islands. Much of that damage was due to erosion and sediment damage.

B. APPROACH TO THE PROBLEM

Soil erosion and sediment deposition in this region is largely the result of the action of rainfall and subsequent runoff. The tools we possess to control erosion and sediment are numerous and other presenters have covered important facets. The basic goal is to minimize soil erosion from occurring and to stabilize sediment which is generated. Structural methods, the topic of this paper, is utilized in concert with other approaches. The spectrum of erosion and sediment control is briefly listed below:

1. Design and plan a project with soil erosion and sediment control as a design objective - do not view it as a quick fix just to get permits. In all cases design a project with the minimum area of disturbance.

2. For larger projects or those situated in sensitive environmental areas, phasing of site work and exposure to seasonal weather patterns can be critical. The site's degree of exposure to erosion both in area and time needs to be minimized.

3. Rapid stabilization of disturbed areas is necessary to limit the exposure risk of erosion. Here structural methods begin to interact with vegetative methods in stabilizing and protecting soil from water erosion.

Structural methods are an integral part of the comprehensive soil erosion and sediment control program. The three overriding principles of erosion and sediment control are:

1. Minimize the soil erosion process from occurring at the construction site on area which must be disturbed. This is accomplished by protecting exposed soil from rainfall impact and controlling water run off.

2. Sediment control is a backup for erosion control measures, it is a second line of defence to capture soil which could not be successfully retained by erosion control methods.

3. The coordination of erosion and sediment control with water flow/storm water management both on site and leaving the site to obtain a comprehensive and well managed program.

A number of specific structural methods are discussed below which is followed by graphic examples after the text and cut sheets from manufacturers. Illustrations are taken from the Urban Land Institute publication Residential Erosion and Sediment Control, 1978. The cut sheets are referenced in the text by their manufacturers name which however does not endorse the product. Other manufactures not listed produce similar products.

C. STRUCTURAL METHODS

Structural methods are presented in three categories: 1. Erosion control, 2. Sediment control and 3. Disposal structures. All methods are not applicable at every site and careful planing and design is crucial for the steep terrain encountered on many Caribbean islands.

C.1. EROSION CONTROL

After site planning and design to minimize soil erosion, the treatment of areas which are disturbed by earth moving activities through erosion control methods is necessary. These fall into two basic and interrelated methods, vegetative and structural.

Structural erosion control has a basic objective -

> Prevent or minimize rain fall run off from dislodging soil particles either from direct rail drop impact and from the scouring action of running water over vulnerable soil.

Shielding of exposed soil is accomplished by vegetative measures, which is the topic of other papers presented at this conference, and by artificial or structural means. Literature on some commercial soil protective coverings are included at the end of this pater. A variety of several artificial soil coverings are listed below:

1. Straw mulch of chopped straw will protect soil surfaces from direct rain fall impact and keep moisture to foster vegetative growth. It is available commercially in rolls and reinforced with either natural or artificial webbing or mesh to hold the straw in place. It requires pinning to the ground. It is easily applied and is limited to areas which are not subjected to large volumes of concentrated water flow. Various thickness and mesh strengths, including shredded coconut fiber, can be applied as soil stabilization liners in small ditches. (American Excelsior Co.,North American Green, Enka)

2. Hydro mulch is a liquid suspension sprayed from a pressure sprayer. A mix of paper strips or straw chips, water, grass seeds and a binder is projected from a sprayer over exposed soil surfaces. It is a quick and efficient method of protecting exposed soil surfaces. It is limited to areas where protection from rain drop impact is needed and is not applicable for swales or drainage ways subjected to concentrated water flow. Due to the expense of mobilizing this equipment it is limited to larger construction jobs. It had been used for the St. Thomas Hospital renovation several years ago. Prices range from \$0.10 to \$0.40 per square foot.

3. Other proprietary fibrous applications of woven jute mesh, stranded fiberglass applied by air pressure, shredded wood held together with paper net and similar material combinations are available as commercial products. For island applications, shipping cost and local availability are critical factors, especially for small construction works.

The other critical consideration in erosion control is to prevent water run off from reaching exposed soil areas or to prevent the accumulation of run off which can seriously damage exposed soil areas. This is accomplished by a variety of water diversion structures which drain water towards stable areas or existing water ways. Detailed design criteria can be found in the V.I. Environmental Protection Handbook, manufacturer's literature as well as text books on the subject. Structural erosion control methods can be described as follows:

1. Diversion berms and or ditches constructed at the top of exposed slopes to intercept and divert water flow towards stable receiving areas. These structures can either be temporary for the duration of critical soil exposure or permanent to provide long term erosion protection. It is constructed along the contour with a slight slope in the range of 2 to 5 percent, to prevent erosion in the ditch. Inspection after storm event is necessary to spot and repair weak areas.

2. Temporary filter berms are stepped down a cleared slope to shorten the vertical runoff flow distance. They are similar in function to diversion berms in that they intercept runoff. The are constructed on the contour or at a slight grade to channel runoff onto stable receiving areas. Temporary filter berms have found broad application in the islands where mechanical brush clearing is done. A mixture of a soil and brush is scraped into berms parallel to contours at interval of 50 to 100 feet. The soil/brush berms retain sediment as well as filter runoff to some extent. Such temporary structures are reasonable effective for average storm events. A field study performed on St. Croix on a cleared 13.4 acre site protected with temporary filter berms, with a land slope of 25 percent, showed erosion production of 0.018 tons per acre. This sediment yield was low compared to other study sites. If sensitive areas lie down slope of such cleared zones then additional protection will be needed. More permanent variations of the same concept are farm terraces found in mountainous area such as the north slopes on St. Thomas.

3. Wattling is a special manual method of stabilizing steep slopes. Closely spaced (1 to 3 foot spacing) hand dug furrows are constructed parallel to contours. Tied bundles of green brush, such as Tan Tan, are placed into the furrows and staked into the ground making a continuous row of bundles. Earth is back filled into the brush bundles leaving them as ridges along the contour. The green brush cuttings will soon sprout adding to the structural stability of the slope. This method is labor intensive and is limited to steep slopes where machinery cannot operated and other erosion control methods may not work. Locally available resources are used for this method. Such application was successfully used to

stabilize steep slopes in the Bordeaux housing development on St. Thomas. (ASCE, 1980)

4. Diversion dikes are constructed across graded roads or minor drainage ways to intercept runoff and direct it to stable receiving areas or towards sediment control structures. They require frequent inspection and maintenance due to damage from vehicular traffic. They are intended as temporary measures until disturbed areas are stabilized or in case of roads, paved. A note of caution, never attempt to interfere with or disturb the steep natural water ways or guts found in the mountainous areas of the islands. Only well engineered and constructed structures will withstand the flash flooding.

5. Road Bed Paving. Dirt road ways, in land subdivision and other developments, particularly in steep terrain, are a major soil erosion sources. Usually roads are steep and act as water interceptor structures from uphill drainage areas thereby accumulating large runoff quantities. Paving of road ways, stabilizing of ditches and installation of drainage structures are important structural erosion control measures. It is probably safe to say that on islands of steep terrain, dirt road ways without well designed drainage facilities are major sediment contributes. A soil erosion investigation on St. Thomas/St. Croix showed that steep dirt roads generate 10 times the quality of sediment compared to a housing construction site. Sediment produced by a freshly graded road generated 197 tons per acre, an old (not fresh graded) dirt road produced 25 tons per acre while a housing construction site produced 19 tons per acre. (DCCA, 1986).

Variations of erosion control methods is only limited by inventiveness. New products are coming on the market which make erosion control efforts more effective and lower cost. But as with any new product, the manufactures claims must be tried in actual field conditions. Careful evaluation of such products that they live up to their claims is always warranted.

C.2. SEDIMENT CONTROL

Erosion control attempts to protect existing disturbed soil areas from erosion. This is frequently not entirely effective and backup sediment control structures must be employed. Although such structures are generally thought of as applying to larger projects, they are also effective for small developments even house lot construction.

The basic mechanism of sediment structures is to slow down the water flow allowing sediment to settle. Larger particles settle more quickly than smaller ones due to their greater mass. Very small particles like clay will stay in suspension due to electrostatic charges for time spans much longer than can be practically achieved with sediment structures. Sediment control is also achieved by filtration through fabrics. A listing of basic sediment control methods is given below, and here again is not an exhaustive list as many variation are possible both in choice of material and design.

1. Inlet Barriers. Gravel or straw bales are placed in front of storm drain inlets in order to trap sediments and prevent their passage into the drainage system. Reinforcement of gravel barriers with hollow concrete block will improve the stability and prevent gravel from being washed into the drains particularly if large water flows can be expected. Straw bales are an option and must be staked to the ground. Embedding of the bales a few inches into the ground will prevent piping of water and sediment below bales. Both measure are temporary, must be inspected after storm events and be removed when soil areas are stabilized.

2. Rock Check Dams. Usually temporary installations placed in road side ditches or other small ditches to slow the velocity of water flow thereby reducing its scouring capacity and providing some sediment retention. Rocks range in size from 4 to 12 inches diameter preferable well graded with placement intervals at 50 feet or less. Maintenance checks and repairs are necessary after storm events and due to vehicle damage as well as cleaning out accumulated sediment. Check dams are particularly useful as temporary erosion/sediment control on dirt roads until paving stabilized the road bed.

3. Straw Bale Sediment Barriers. These are temporary installations which retain sediment by retarding runoff and filtration. They can be used in combination with gravel filter outlets and are useful as a perimeter enclosure for disturbed areas where erosion control is not possible. Bales are firmly pinned to the ground, and a shallow trench into which bales are placed will prevent piping of runoff below bales. Use of untreated wood stakes for fastening the bales to the ground will eliminate the need and cost of removal, both bales and stakes will deteriorate and be merge into the environment. Frequent inspection is necessary to ensure their effectiveness. Straw bales are inexpensive and available in agricultural regions and hence not readily available for areas like St. Thomas. They are usually shipped into the islands with other materials for larger jobs.

4. Silt Fences. Preconstructed or job fabricated silt fences have come into common use in this area. They are compact when stored and do not degrade like straw bales. Their function is similar to straw bales except removal is necessary after use. Various fabrics are in use to retain sediment and filter runoff. Most manufactures provide installation instructions. Key elements are sturdy supporting stakes and burial of the bottom edge in the ground. The failure to provide the latter is frequently observed and it allows escape of sediment runoff below the fence, making the entire effort a futile gesture. Silt fences can also act as water diversion structures to channel runoff to specific areas.(Geofab, Moore & Assoc, Amoco)

5. Sediment Traps. Traps are pits of various sized dug into the ground at strategic locations to trap sediment from runoff. With excavation equipment they are easy to construct and several on one site can substitute for a larger, more expensive sediment basin. Sediment must be periodically removed to maintain efficiency of the structure. When sixty percent of the original volume is filled, the structure needs to be cleaned out. Although their most effective use is on relatively gentle sloped sites where rock is not present to impede excavation, they also have a place on steeper sites, where smaller well placed pits can effectively trap the coarser gradation of sediments and prevent their discharge off site. The VI Environmental Protection Handbook recommends a minimum sediment storage volume of 0.5 inches over the drainage area. If external runoff is diverted from the site with diversion berms or ditches and runoff from a site is limited to the disturbed area, then a 1/4 acre construction site will need a trap of 17 cubic yard minimum volume. This is a pit 3 feet deep, 10 feet wide and 15 feet long.

6. Sediment Basins. These are fairly large and specially designed structures primarily limited to larger construction sites. In some cases they also function as flood mitigation structures. Specific design criteria are found in the V.I. Environmental Protection Handbook. Some of the major design criteria are:

Drainage area from 20 to 200 acres
design storm frequency to 25 years
Dam height maximum of 20 feet
Emergency spillways
Minimum storage capacity of 0.5 inch of drainage area

Larger basins have a pipe spillway which drain basin dry whereby limited flood storage is also achieved.

C.3. RUNOFF DISPOSAL STRUCTURES

Runoff must always be routed either through the site of from the site. Temporary and permanent water ways, channels and ditches can serve this function without erosion if adequately protected. Permanent structures are intended to outlast the construction phase of a project or are installed to solve a particular soil erosion problem. The protective liner of permanent structures depend on the volume and velocity of water expected to be carried. This protection is either by vegetation of artificial means or a combination thereof.

1. Vegetative liners are usually limited to slope ranges from 0.25 % to 2%. Maximum water velocities range from 3 to 7 feet per second depending on the erodability of the soil which can be found in the Soil Survey for the Virgin Islands. These limiting parameters make vegetative liners suitable only for flat flood plains on the mostly steep islands of St. Thomas and St. John and for large gentle sloped areas of St. Croix. Detailed design tables and procedures are found in the V.I. Environmental Protection Handbook and other literature sources. For steep sloped channels, liners must be of man made materials designed to resist the scouring velocity of fast flowing runoff.(American Excelsior Co., North American Green, Enkamat, Greenstreak)

2. Artificial liners are produced to supplement vegetative covering or entirely made of man made materials. The latter include concrete, asphalt, metal, stones, gabions (rock filled wire baskets), plastics and similar durable material. The cost are higher than other coverings and their application is limited to sites where less durable liners would fail. Frequently combinations are possible to reduce cost. A channel with it lower portion of concrete and upper side slopes vegetated will cost less than paving the entire channel. Hydraulic evaluation is needed to determine the level to which paving must be used.

Between the soft natural vegetative liners and the hard man made ones, there is available a variety of soil reinforcing fabrics and coverings which will tolerate greater water depths and velocities. These are briefly listed below and copies of manufacture catalog cuts are attached at the end of this paper:

Erosion control matting is produced both from manufactured materials such as nylon fabric fibers

or similar materials or from processed natural sources including paper, straw, jute, wood excelsior and other biodegradable materials. Netting is commonly used to hold the fibers in a blanket which is rolled over the soil. Embedding of edges and staking a intervals is necessary to hold the matting in place. Proper installation is critical to satisfactory performance of the materials. According to information presented by manufacturers, maximum water velocities of 17 feet per second and water depths of 2.5 feet can be sustained by the nylon matting (Enkamat). These materials are light weight, although bulky, and are easily applied. Some manufactures produce matting with embedded grass seed.(American Excelsior Co., North American Green, Enkamat, Greenstreak)

'Geoweb'is a trade name of a cellular confinement structure made of a plastic. Attached cells with open top and bottom are filled with soil or gravel to provide a erosion resistant blanket. Experience with this product is limited but it may have potential applications. (Presto Products Co.)

A variety of structural erosion control and sediment control methods have been presented. Where soil must be disturbed for construction or other activities, erosion needs to be minimized from taking place and that which does occur be retained with sediment control structures. The objective is to keep erosion rates to natural levels. Accelerated soil erosion is detrimental and costly to natural environments and man made facilities.

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HOW TO PREPARE AN EFFECTIVE EROSION & SEDIMENTATION CONTROL PLAN

William F. McComb, P.E.

W. F. McComb Engineering, P.C., 129 Sub Base - Chinnery Building, St. Thomas, USVI

The preparation of an effective erosion and sedimentation control plan (ESCP) is not only based on engineering and scientific principles but also on the experience and knowledge of the designer. There can be several approaches to and designs of a good ESCP, all of which will be acceptable and achieve the desired results. Thus the evaluation of any ESCP must be done with an open mind and no pre-conceived ideas.

One thing that you must remember is that an ESCP is just part of the Earth Change Permit Application. The ESCP deals only with the control of erosion and sediments. It does not dictate the extent of earthmoving, site disturbance, building location, etc.. These aspects are within the realm of the Designer. It is hoped that the designer will take erosion and sediment runoff into consideration, but there is no guarantees. In big projects it is likely that someone other than the designer will do the ESCP and that person is not apt to have much control on site design. For smaller projects it is likely that the same person will do both and this should be reflected in the impacts that the site plan will have on the ESCP. The Govt. review of the Earth Change Permit Application is important in that the reviewer can assess the impacts of the site design on erosion and sediment generation and suggest to the designer changes that will lessen this before it is approved.

All ESCP's want to:

a. Reduce erosion to a minimum and minimize the time period for this to occur.
b. Control the direction and if possible the flow and velocity of runoff.
c. Keep sediment runoff from the site to a minimum.
d. Control stormwater runoff through the site and its effects on downstream properties.

In order to give some guidelines on how an effective ESCP can be prepared, I will use a Subdivision that I am designing now as an example. The parcel is 3.40 acres in size, zoned R-2 and located in Estate Wintberg. It has been subdivided into 11 parcels. Figure 1.

The low point on the property is in the middle of the north boundary. The total drainage area to this point, including the parcel itself, is approximately 7.17 acres. Using the SCS TR-55 method to estimate the stormwater runoff in small watersheds, the peak discharge when the site is fully developed for 50 yr. storm is 124 cfs. Figure 2. I will not review this Method as it will be described in detail later on this afternoon. These figures are important in order to size any drainage structures needed.

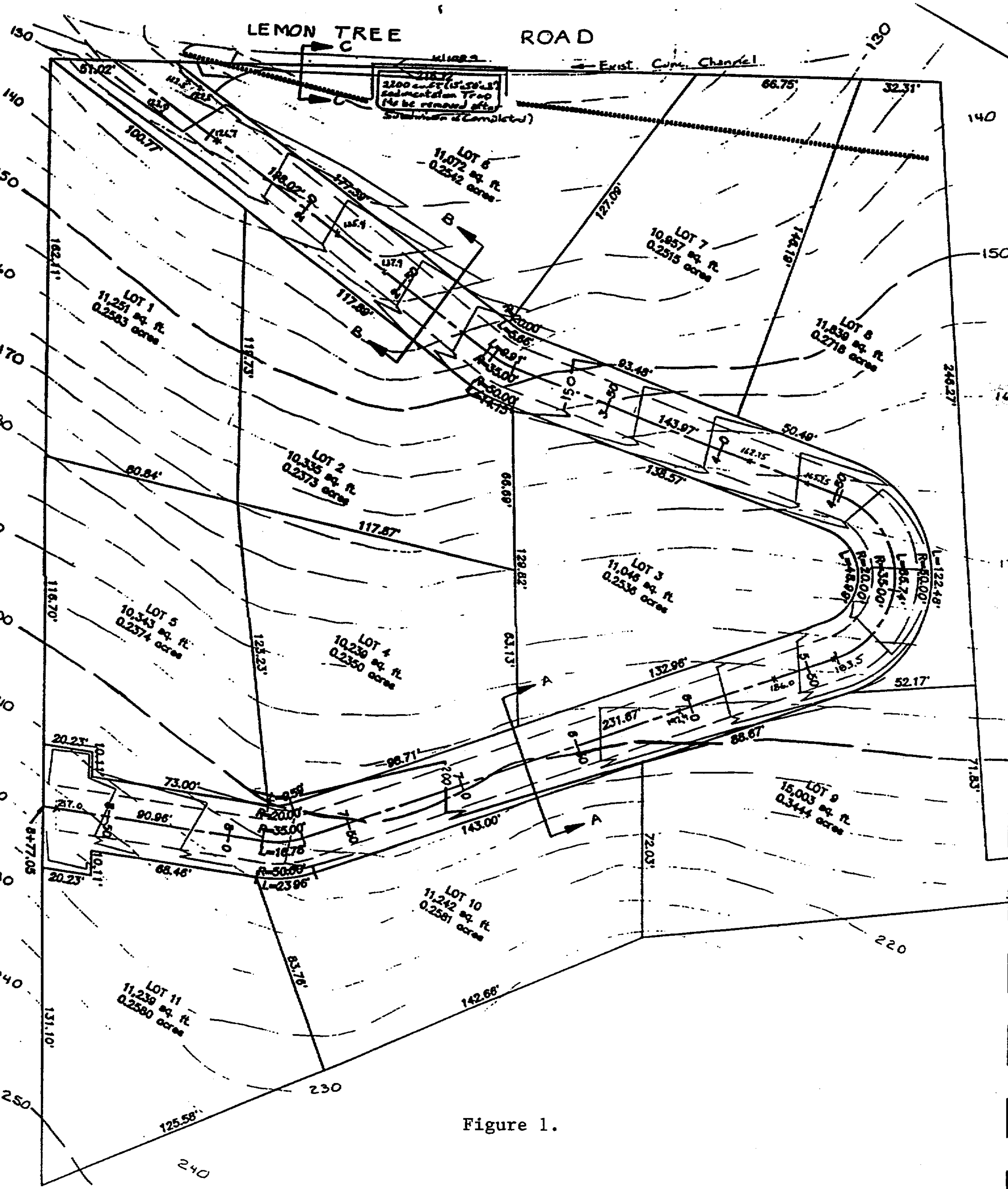

LEMON TREE ROAD
Exist. Conc. Channel
LOT 1
11,251 sq. ft.
0.2583 acres
LOT 2
10,335 sq. ft.
0.2373 acres
LOT 3
11,046 sq. ft.
0.2536 acres
LOT 4
10,239 sq. ft.
0.2350 acres
LOT 5
10,343 sq. ft.
0.2374 acres
LOT 6
11,072 sq. ft.
0.2542 acres
LOT 7
10,957 sq. ft.
0.2515 acres
LOT 8
11,839 sq. ft.
0.2718 acres
LOT 9
15,003 sq. ft.
0.3444 acres
LOT 10
11,242 sq. ft.
0.2581 acres
LOT 11
11,239 sq. ft.
0.2580 acres

Figure 1.

Project : 1X1 ESTATE WINTBERG
County : ST. THOMAS State: VI User: JEM
Subtitle: SUBDIVISION DESIGN Checked:

Data: Drainage Area : 7.17 * Acres
Runoff Curve Number : 83 *
Time of Concentration: 0.02 * Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1	2
Frequency (yrs)	25	50
24-Hr Rainfall (in)	9.0	10.4
Ia/P Ratio	0.05	0.04
Used	0.10	0.10
Runoff (in)	6.94	8.29
Unit Peak Discharge (cfs/acre/in)	2.083	2.083
Pond and Swamp Factor 0.0% Ponds Used	1.00	1.00
Peak Discharge (cfs)	104	124

* - Value(s) provided from TR-55 system routines

Erosion and sedimentation control are two different items. Erosion is the effect of stormwater runoff eating away at exposed surfaces. Sediments are the materials which are eroded from the soil and carried away by stormwater. Both of which are controlled in similar and different ways.

EROSION CONTROL

One of the main means of controlling erosion is to divert runoff from the exposed soil, particularly during construction. After construction, the best way to control erosion is to have re-vegetated the exposed soil. For the example given, I looked at the possibility of diverting the runoff from the construction (cutting of the subdivision's road). To do this a diversion ditch would have to be constructed uphill of the road. Because of the slopes, the extreme difficulty in digging this ditch and the construction impacts, it was decided that this would not be done. What was done was to slope the road into the high side of the site, figure 3 (Section A-A), and allow this to become a controlled runoff ditch, both during construction and afterwards. This also kept storm runoff from running down the filled sides of the road which is more susceptible to erosion than the cut side. Section B-B shows a situation where the road is completely on fill and a berm was used to create the ditch. Figure 4.

Another means used to controlled erosion is that all filled slopes and cut slopes with soil (not rock) would be stabilized with a open web geofabric and planted with ground cover. The geofabr\ic will reduce erosion and provide time and a stable soil surface for the vegetation to grow. See Figures 3 & 4.

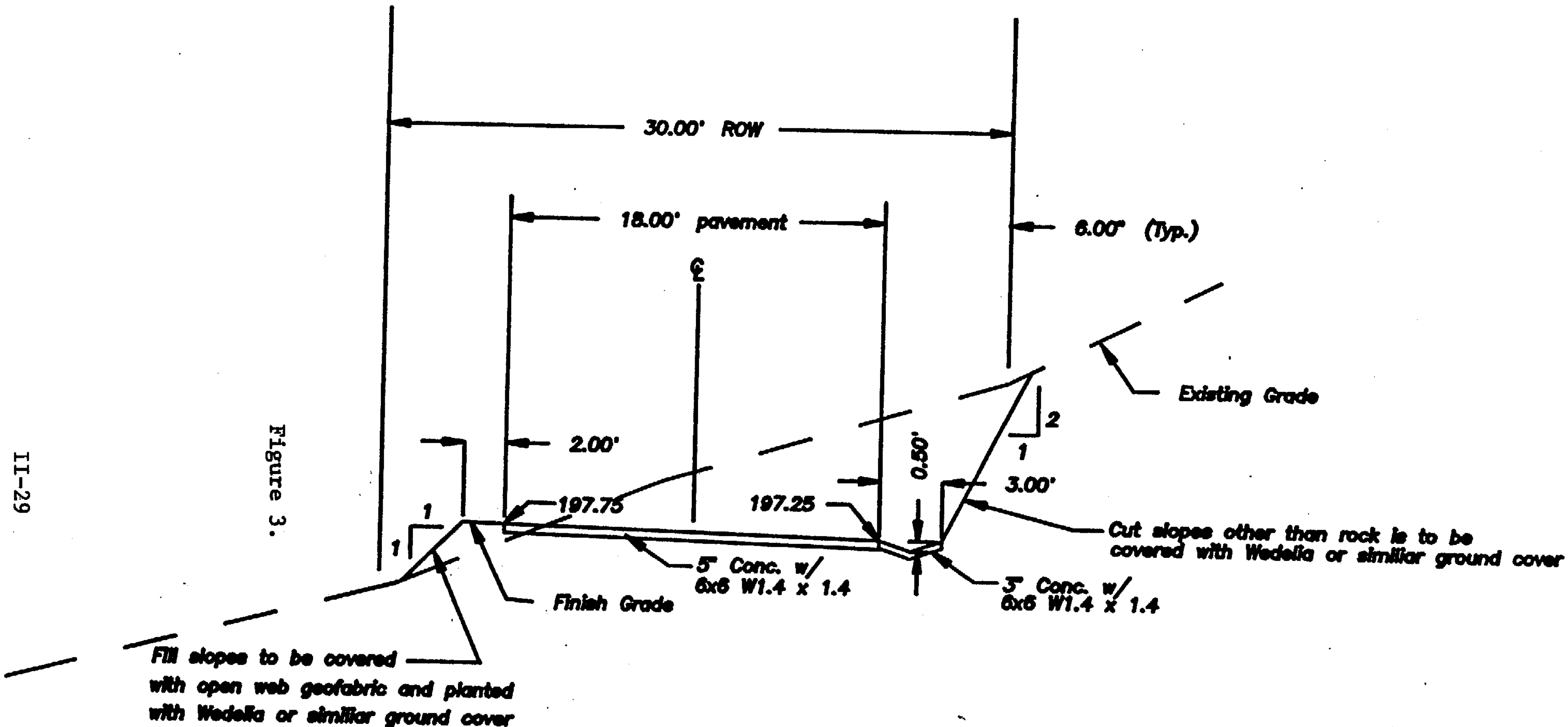
The design of the road cross slope and size of the ditch is based on good engineering design principles for roadways and on the amount of stormwater that has to be carried. The determination of the carrying capacity of drainage ditches, channels, pipes, etc., can be done using the Manning Equation:

$$Q = A \frac{1.49}{n} R^{2/3} S^{1/2}$$

in which:

Q = Discharge in cfs
R = Hydraulic radius (cross section area of flow divided by wetted perimeter)
S = Slope in ft/ft
n = Manning roughness coefficient

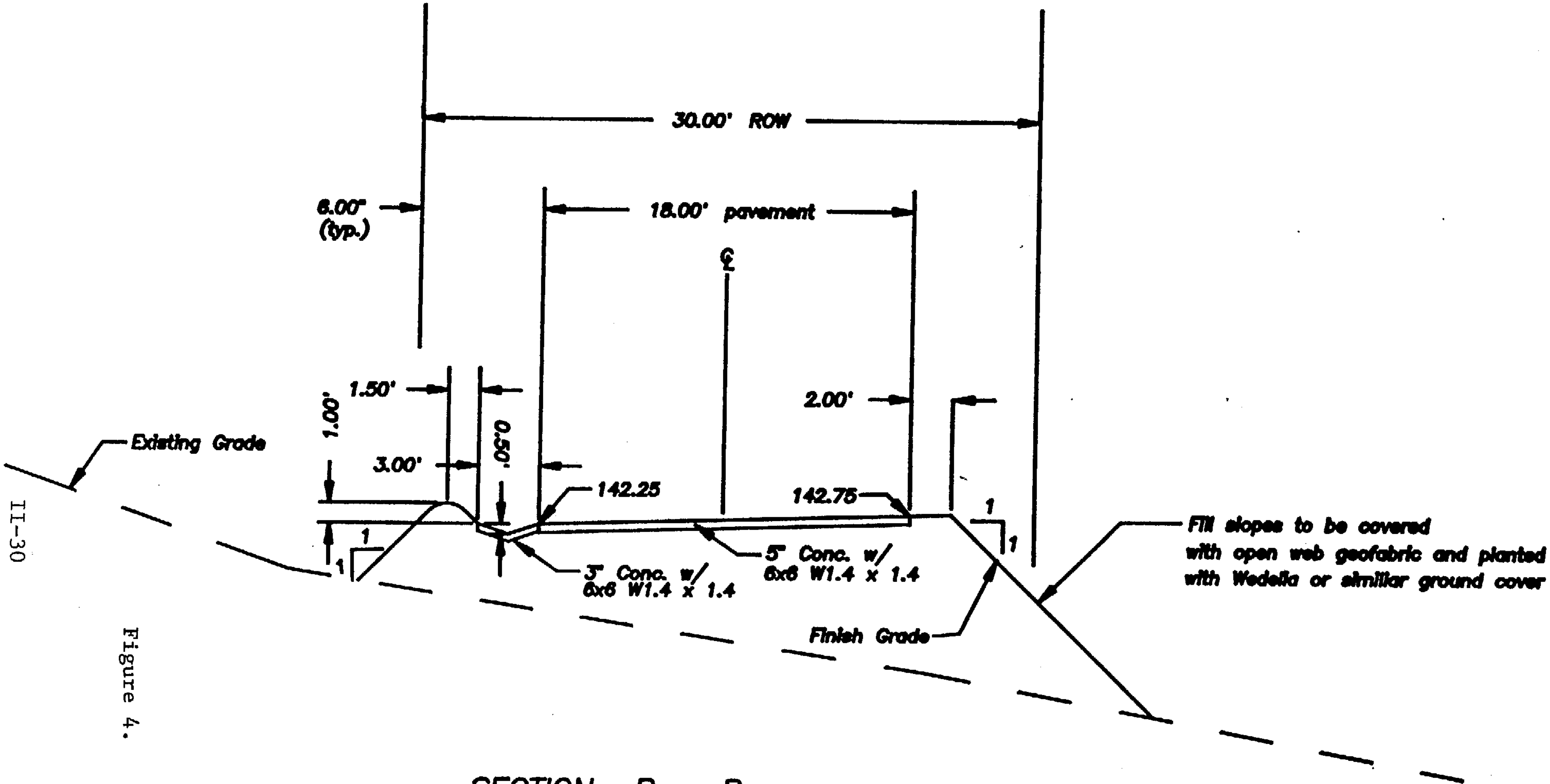
$$\text{Velocity } (V) = \frac{Q}{A}$$



SECTION A – A

Scale: Horz. 1" = 10'
Vert. 1" = 5'

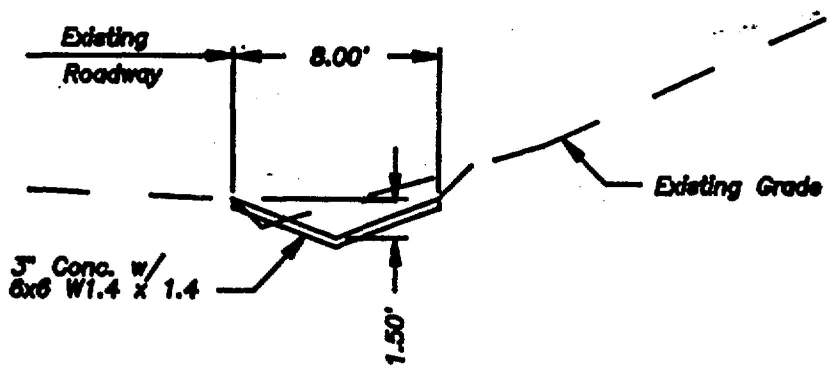
Figure 3.



SECTION B – B

Scale: Horz. 1" = 10'
Vert. 1" = 5"

Figure 4.



SECTION C – C

Scale: Horz. 1" = 10'
Vert. 1" = 5"

Based on this equation the carrying capacity of the ditch at Section B-B is 12 cfs and the capacity of the ditch and roadway is 132 cfs which is greater than a 50 yr. storm. If the carrying capacity was less than the 50 yr. storm, the ditch design and/or the roadway cross slope would have to be changed. The comparison of the capacity against the design storm peak discharge is extremely conservative as the calculated storm discharge was for all 7.17 acres which is only true for the low point in the site. The actual discharge at Section B-B is less as the area is smaller than the 7.17 acres. The capacity of the ditch at Section C - C is 124 cfs, which is okay.

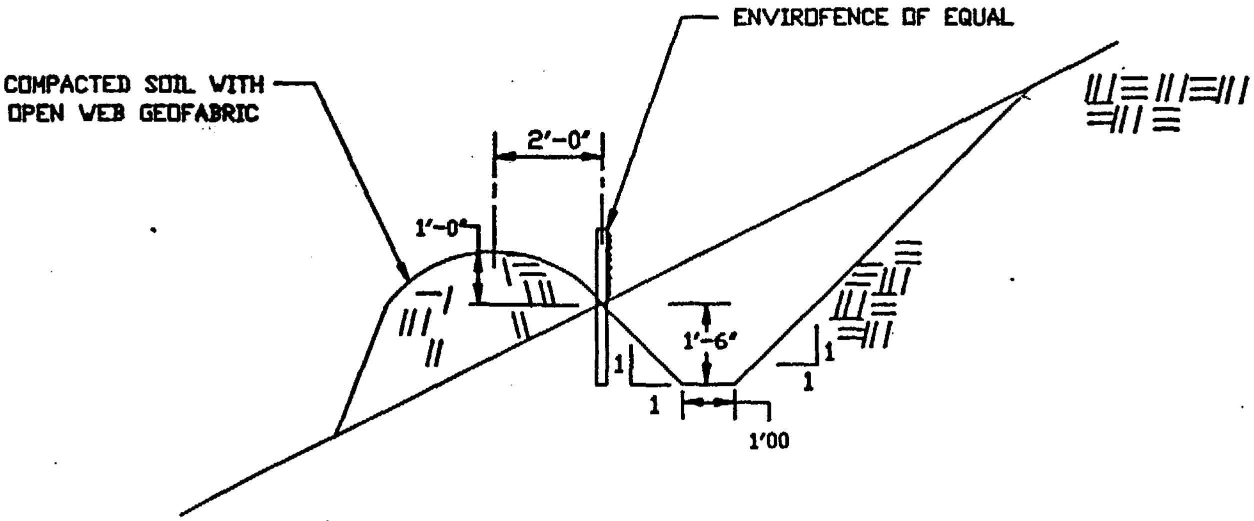
The rate of the velocity of the runoff will also determine what materials will be required for the construction of the drainage structures. For ditches/channels with velocity less than 5.0 fps, vegetated ditches are acceptable. For higher flows, concrete or other durable materials are required. For Sections B - B & C - C, the velocities are 18 fps and 21 fps respectively. For the ditch at Section C - C velocity blocks are recommended. These can consist of concrete blocks set halfway in the concrete, at random, about six feet apart.

SEDIMENTATION CONTROL

Some methods of sedimentation control has already been mentioned, i. e., use of geofabric and velocity reduction. In this example case, a sedimentation trap will be used at low point of the site, see figure 1. A trap of 2,200 cu. ft. will be dug (50'x 15'x 3') and left in place until the subdivision is completed. It will have sideslopes of 2 horz. to 1 vert. and the downhill slopes of the spillway with be covered with nylon matting such as Enkamat. There will be two diversions ditches, see figure 5, directing storm water into the sedimentation trap. Upon completion of all construction, the diversions ditches and sed. trap will be removed. By that time, vegetation will have re-established itself.

The diversion ditch, figure 5, combines the use of a ditch to direct runoff to a specific area and the use of a Silt Fence, figure 6, to control sediments in case the ditch is overtop. For any project, the installation of silt fences is the minimum control that should be used. In areas of large flows and/or steep slopes, it is recommended that the silt fence be supported. In figure 6, we used metal post and 6x6 WWF for backing of the fabric itself.

The principles used in this example can be applied to all other projects including residential construction. The use of diversion ditches, silt fences, planting, sedimentation traps, etc. can easily be done. While they have a cost, it must be budgeted for as we can not continue to pollute our waters.



RUNOFF SEDIMENTATION DITCH

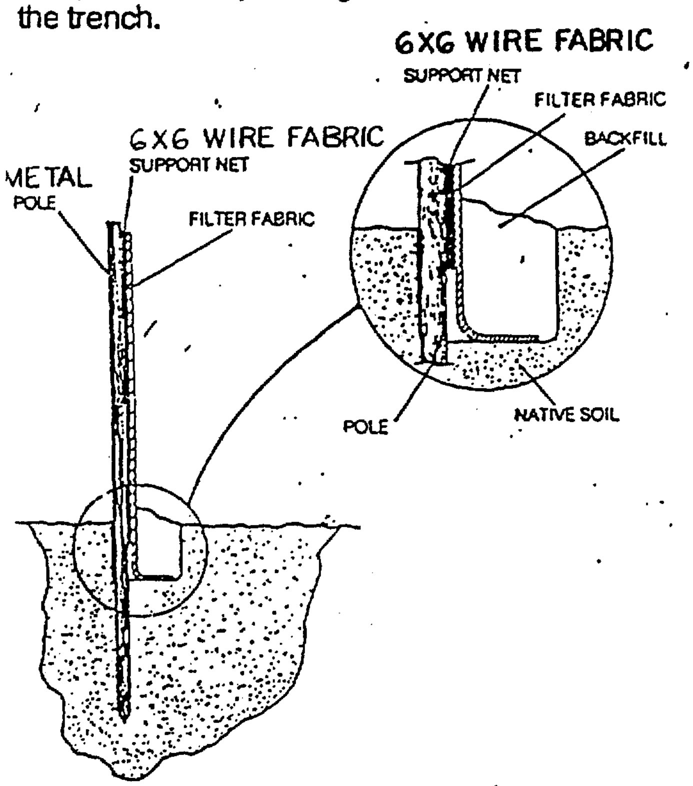
SCALE: 3/8" = 1'-0"

Figure 5.

The Envirofence Package
s designed for easy
field installation:

Suggested Installation Procedures:

- Remove the system from the protective polyethylene bag.
- Unroll the package by sections—pole to pole.
- Dig a 6" × 6" trench around the perimeter of the construction area.
- Place the sedimentation control fabric side of the fence in the direction of the anticipated sediment flow (net side of the system away from the flow) and position the poles against the back wall of the trench.



PLACEMENT OF ENVIROFENCE
INTO TOE-IN TRENCH

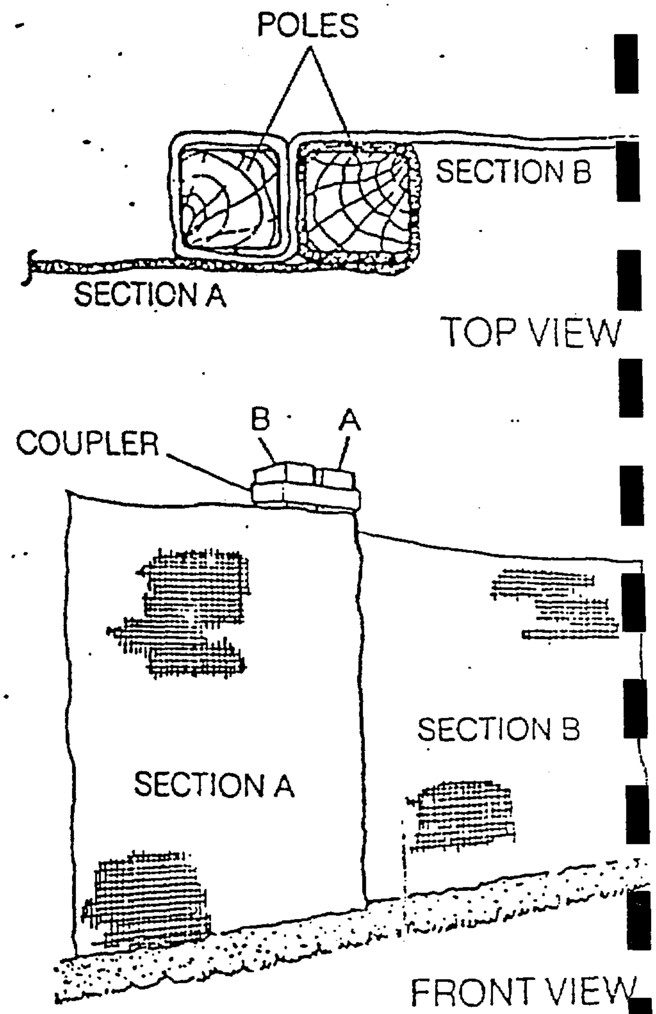
Use a 5# sledge hammer or similar device to drive the poles into the ground until the bottom of the industrial netting is approximately 2" into the trench.

Lay the bottom 6" of sedimentation control fabric into the trench. (The same principle may be employed simply by laying the excess fabric on the ground and piling fill at the base.)

Backfill the trench with native soil and compact, making sure the fabric toe is in place.

Optional Procedures:

- The Envirofence fabric and netting can be ea cut with a knife or scissors to accommodate need for shorter sections. The fabric and net should be cut approximately five inches from last pole. The pole should be rolled to tuck in 5" overlap and to gather two wraps of fabric/n around the pole before inserting into the gro
- A metal coupler is supplied with each system join the end poles of adjacent sections. The in pole of the section to be attached should be serted immediately adjacent to and in front o end poles of the other section, so that they inte lock. The coupler is then placed over and ar the two poles.



COUPLING OF TWO ADJACENT
ENVIROFENCE SYSTEMS

Figure 6.

REFERENCES

1. Virgin Islands Conservation District, VI Dept. of Conservation and Cultural Affairs, VI Dept of Public Works. Environmental Protection Handbook, Third Edition, 1976.

2. US Dept. of Agriculture, Soil Conservation Service. TR 55 - Urban Hydrology for Small Watersheds, 1986.

III
URBAN SOURCES OF NONPOINT POLLUTION (STORMWATER RUNOFF AND POLLUTION PREVENTION)

* *Paper not available at time of printing.*

POLLUTANTS IN STORMWATER RUNOFF AND THEIR EFFECTS ON WATER QUALITY

Marcia G. Taylor

University of the Virgin Islands, Eastern Caribbean Center, Virgin Islands Marine Advisory Service, RR #2, P.O. Box 10,000, Kingshill, St. Croix, VI 00850

Stormwater runoff is the water which flows over land during and immediately following a rainstorm. The types of pollutants that are carried with stormwater runoff is of course dependent on the use of the land over which the rain travels. Rainwater flowing over agricultural land will have different pollutants than that which flows over driveways and roads. Naturally, the types of pollutants in stormwater runoff vary widely. Below I describe the major types of pollutants found in stormwater runoff, their sources, and their effect on the marine environment. I also describe how the pollutant is regulated in the VI, the water quality parameters which measures it, and discuss local monitoring data relevant to the pollutant.

1) Solids or Sediment (suspended and deposited)

This pollutant is the most significant and the most damaging type of water pollutant in the VI. The most common source is from soil laid bare by clearing and grading. When rainwater falls on the soil stripped of its vegetation it picks up large amounts dirt which is carried to the sea.

Many are surprised to learn that naturally occurring "clean soil", or non-toxic particles are pollutants. However, especially in tropical waters, the amount of solids suspended in the water is an important water quality characteristic. In contrast to northern waters, the amount of suspended solids in tropical waters is very low, making water clarity good. As a result, tropical organisms have evolved in and require, clear water.

Sediment in surface waters is measured in several ways, most commonly by measuring total suspended solids (TSS), turbidity, light penetration or secchi depth. Most states and territories have water quality standards for one or all of these parameters. In the VI there is a water quality standards for turbidity, measured in Nephelometric Turbidity Units (NTUs), and secchi depth.

Solids affect marine life in many ways. Dirt and silt particles that enter the marine environment eventually settle to the bottom and can smother marine life. Corals are especially sensitive to this type of nonpoint source pollution. Corals have the ability to clean particles off their surface by secreting a mucous which sticks to the solids and sloughs off. However, this requires the expenditure of a considerable amount of energy which could have been used for growth and reproduction. Corals can survive some sediment stress, but the constant inundation from frequent exposure to sediment-laden water is fatal.

Particulates suspended in the water can also clog fish gills and filter systems in filter-feeding animals and reduce prey capture for sight feeding predators.

Shading is another way sediment affects marine life. Solids suspended in the water reduce water clarity and therefore the amount of light available to marine plants. The discharge of sediment is usually associated with increased nutrients, discussed below.

The effect of introducing solids to the marine environment is not just a short-term threat. Although solids suspended in the water settle and the water becomes clearer, these solids can easily remobilize when disturbed, causing additional impact to the marine biota.

The amount of solids in coastal waters has increased significantly over the last decade. After heavy rains many of the bays have a muddy color which persist for hours or even days. Much of our nearshore coral has been hurt from the increased solid loads which enter our waters.

2) Nutrients and Organic Materials

When organic material is introduced into surface waters they increase the amount of nutrients, or nitrogen and phosphorus in the water. This occurs when rain water runs over failed septic leach systems or other areas where there are nutrients or organic wastes such as livestock areas, and fertilized areas. Although marine plants and animals like other living things need nutrients, an excess can be harmful. Tropical marine life has evolved to live in nutrient-deficient waters where even small increases in nutrients can be harmful.

The additional nutrients can drastically upset the water's chemical balance which can result in blooms of fast-growing species such as algae. The growth of these species can impair growth and reproduction of the naturally occurring species such as coral, which competes with algae for space.

The addition of nutrient and organic material can also affect marine life by decreasing the amount of oxygen available. During the breakdown of organic matter by microorganisms, oxygen is used, making it less available to fish and other organisms who need it. Dissolved oxygen levels can be reduced to levels lethal to marine life causing massive kills of fish and other species.

Nutrients in the water can be measured by several water quality parameters such as nitrite, nitrate, ammonia, and phosphorus. Most states have standards for at least one of these parameters. In the VI there is a water quality standard for phosphorous.

Excessive nutrients are a problem in many of our bays, however there is little water quality data which shows this. Standard methods of measuring nutrients are not always sensitive enough to show the increases in nutrients in our waters. More sensitive methods should be employed when analyzing tropical waters for nutrients.

3) Heavy Metals

Heavy metals are often introduced into through stormwater runoff. The heavy metals having the highest concentration in urban runoff are copper, lead, and zinc, with cadmium being a distant fourth. In industrial areas and areas where sanitary and storm water get mixed, other metals such as chromium, mercury, nickel and selenium, arsenic can be commonly found.

Heavy metals are of concern because of their toxic affect on many marine organisms, and those who eat them, including man. They can affect the reproduction of fish, and accumulate in their tissues.

Metals are not routinely monitored in the VI largely due to the cost. The VI does not have numeric water quality standards for heavy metals, unlike all other states and territories. However, the US EPA has monitored the water and sediment in the VI and identified several areas where levels are high. Bays with marinas often have high levels of copper, zinc and lead. Industrial areas also tend to have elevated levels of many of these metals. In many cases the levels found in these areas exceed National guidelines.

4) **Hydrocarbons** (oil and grease)

Hydrocarbons, such as oil and grease, are picked up when stormwater runs over parking lots, roadways, and industrial sites. It can also be introduced when there is illegal dumping of waste oil. These substances are often toxic to many organisms in low concentrations, and other organisms assimilate it into their tissues, tainting it for human consumption. Floating oil decreases the amount of light to benthic organisms and cuts down the amount of oxygen transfer across the air-water interface.

Oil and grease are measured in a laboratory in milligrams per liter (mg/l). Although the VI does not have a numeric water quality standard for hydrocarbons, at many of the industrial facilities their discharge permit requires that their stormwater cannot exceed 15 mg/l.

Although hydrocarbons entering the sea through stormwater have not been shown to caused significant destruction of our marine resources, in several areas it is a problem. Oil sheens are commonly evident around industrial areas after heavy rains. Some are obvious by the rainbow colored sheen, although some hydrocarbons do no leave a sheen.

5) Pathogens (Coliform bacteria and virus)

Pathogens can be introduced into the surface waters when stormwater runs across failing septic systems or land with animal wastes. Or there can be leakage from sewer lines which can be washed to sea.

To detect the presence of bacterial contamination we test for the indicator organism fecal coliform. To determine if the source of the contamination is from human or animal waste, we test for both fecal streptococcus and fecal coliform. To protect public health, the VI has a water quality standard for fecal coliform.

Increased levels of pathogens can pose a health risk and close or restrict use of shellfish beds. We have seen an increase in bacterial contamination as more and more land is being developed. It is not uncommon for coastal waters to exceed bacterial levels for swimming after heavy rains. This occurs commonly in many bay around the Territory.

6) Toxic Organics

Toxic organics such as pesticides and polychlorinated biphenyls (PCBs) can be extremely damaging to marine organisms. In addition, they can accumulate in tissues and cause it to be unfit for human consumption.

The VI does not have numeric water quality standards for these substances, nor do they routinely monitor for them. Federal monitoring studies have not identified these pollutants as causing significant degradation in the VI.

In general the effect of pollutants on the marine environment depends on many things such as their toxicity, the concentration, and where they are discharged. Because of our tropical environment, local plants and animals tend to be more sensitive to some types of pollutants than plants and animals in colder areas.

Planning is necessary in order to protect water quality from the pollutants in stormwater runoff. The waterbody's watershed must be carefully studied, identifying drainage ways, flow patterns, and geologic features such as permeable soils, and bedrock. The sources of pollutants and the resources affected by runoff must be identified. Once this is done, Best Management Practices (BMPs) which are appropriate for the conditions and concerns should be identified and installed. Monitoring of stormwater and ambient water quality should be implemented to check the effectiveness of the methods.

GOOD HOUSEKEEPING PRACTICES TO MINIMIZE POLLUTION

Timothy J. Cunningham

Office of the Governor, Virgin Islands Energy Office
St. Croix, U.S. Virgin Islands 00820

We cannot wait for an emergency to act on our management of what we consider to be "waste." Waste is defined by Webster's dictionary as "to fail to take proper advantage of."

There are many inexpensive and proven methods by which we can manage our "resources" in a responsible and advantageous manner. The methods by which we discard our resources are placing our land, our sea, our tourism and our health in jeopardy. By irresponsibly discarding that which can be reused or recycled, we are increasing the size of our dumps, contributing methane (greenhouse gas) to our atmosphere, and contaminating our groundwater.

In the Virgin Islands, we have the opportunity to use proven methods from around the world to recover our resources and prevent pollution. Basically, we need to re-think how we define sustainability. We can promote jobs and awareness of our wasteful habits hand-in-hand.

The Virgin Islands Energy Office Resource Recovery Program provides technical support to the private sector and government agencies on reusability, recyclability, and financial opportunities. Working closely with local agencies, federal agencies, the private sector, and non-profit groups information is obtained and disseminated throughout th territory.

I am going to provide you with current "waste management problems and their solutions being addressed by the Virgin Islands Energy Office in conjunction with other agencies. In addition to the government solutions, you will be provided with techniques that can be applied at home and work to minimize pollution.

One such government project involves Energy Office financial and technical assistance to the Department of Public Works Environmental Services Division in establishing composting demonstration sites at nurseries and providing a limited number of homeowners with composters throughout the territory.

In addition, VIEO has identified FEMA matching funds that will assist DPW in acquiring equipment for a large scale composting facility proposed for the Anguilla Dump. These projects will demonstrate the feasibility of recycling food, yard, wood, and paper wastes as a means of conserving water, fertilizer, and valuable landfill space. An estimated 23,000 tons of paper waste; 15,000 tons of food waste; 5,000 tons of yard waste; 3,000 tons of wood waste; and 2,200 tons of miscellaneous organics is generated on St. Thomas annually. An estimated 2,000 tons of paper waste; 350 tons of food waste; 114 tons of yard waste; 80 tons of wood waste; and 26 tons of miscellaneous organics is generated on St. John annually.

At home and work the problem can be addressed by composting our food, paper, yard, and wood wastes. In April, the Energy Office hosted a series of composting workshops in both districts. The workshops defined the methods, benefits, and importance of composting as an integrated waste management strategy. Workshop packets are available free of charge. The widespread use of composting as a means of minimizing pollution can be facilitated by enacting a ban on yard and wood waste disposal at the dumps, and by amending the VI Clean Air Act to ban the practice of openly burning wastes as permitted by the VI Fire Service.

The Used Oil Interagency and Ad Hoc Committee has been meeting monthly since February to establish a permanent Territorial used oil management plan. The improper storage and disposal of used oil poses a threat to our soil, groundwater and sea. By dumping oil on the ground we reduce soil productivity and threaten groundwater. One gallon of oil can contaminate one million gallons of water. The Energy Office will be establishing two demonstration sites on each island for a total of six sites that will demonstrate the reusability of used oil as a fuel extender. A portable machine will be placed at each site that will filter used crankcase oil and blend it at a ratio of 5 percent with diesel fuel to be burned within the engine. In addition to using used oil as a fuel extender, it can be used as boiler fuel for power generation and as an additive in asphalt paving.

At home and work we can address the problem of crankcase oil by changing our oil in a responsible manner. Avoid spilling oil or mixing it with any other liquids or dirt. Pour oil into a clean, sealable container, preferably metal. Do not allow anything else besides crankcase oil to be mixed with the oil. Store in a cool place away from direct sunshine and heat. If oil is accidentally spilled, do not wash off ground with water, it will only compound the problem. Soak-up the oil with either kitty litter or another material on the market. To obtain information on how you can participate in the Used Oil Program contact Department of Planning and Natural Resources, Division of Environmental Protection, Laura Hassell.

Aluminum cans are the most widely recycled item throughout the territory. An estimated 1,000 tons and 50 tons of aluminum cans are generated annually on St. Thomas and St. John respectively.

The Anti-Litter and Beautification Commission should be commended on their work in promoting aluminum can recycling and for their perseverance during difficult financial times. At home and work, a separate bin can be placed for the storage of aluminum cans for redemption. By recycling one aluminum can, you eliminate 90 percent of the energy it would take to manufacture a can from virgin materials.

The incredible amount of energy expended on aluminum manufacturing, and the waste generated during manufacturing, is typified by visiting the Virgin Islands Alumina Corporation. Fortunately, there are many things that can be done with bauxite tailings (red mud). Since May, VIEO has been working closely with Terra Technology to expose them to the US Bureau of Mines, US Small Business Administration Pollution Control Loan Program, the Industrial Development Commission, and the National Institute of Standards and Technology. Terra Technology is a company that has been researching the potential of manufacturing ceramics, floor tiles, roofing tiles, and cement bricks from VIALCO's waste stream. Terra Technology was pleased to discover, through VIEO, that bauxite tailings have been used for many years in ceramics, as a concrete pigment, PVC strengthening agent, road bed surface, as filtration for septic systems, construction of wastewater ponds, and in the construction of low income housing as is being done in Jamaica.

The photocopier toner cartridge is receiving increasing attention as a recyclable item because of its need for periodic replacement. The photocopier toner cartridge recharging market has greatly expanded throughout the United States and Puerto Rico. Most people consider the cartridges as disposable and discard them. Toner cartridges can be recharged at locations on all three islands. Recharging the cartridge costs half as much as a new cartridge and eliminates the bulky plastic cartridges from ending up in the dump.

Our dependence on batteries poses another type of problem. An estimated 76 tons and 4 tons of batteries are generated on St. Thomas and St. John respectively. If not recycled, batteries can be a source of potential groundwater pollution. Disposable batteries can be replaced with solar powered items that do not require a replaceable battery. If you must purchase batteries, rechargeable Nickel Cadmium and a new generation of environmentally benign batteries are readily available. They have a much longer life than disposable batteries and save the user money in the long run. K-Mart Department Stores are accepting used 6 Volt and 12 Volt batteries to be shipped off-island for recycling.

Purchasing water in refillable three or five gallon bottles, or better yet purchasing a water filter will alleviate plastic waste disposal. It will save you money and eliminate the one gallon jugs from going to the dump. If you choose to purchase water in a one gallon jug, refill it at a water dispensing machine, or reuse the jug for used oil storage.

This leads me to the concept of waste reduction through selective purchasing. If consumers are educated on the benefits of purchasing products manufactured from recycled materials versus virgin materials, consumers prefer to purchase products made from recycled materials. Assume a basic supply and demand principle: the more we demand, the more products will be available. This will allow competition to drive the prices down to be competitive with products made from virgin materials. Re-refined motor oil, recycled paper products, factory reconditioned items, and retreaded automobile tires are just a few examples of products that both the Department of Property and Procurement and the private sector can be supplying to stimulate the recycled products market.

In keeping with the presentation title, I will mention techniques to minimize water-borne pollution. Faucet aerators, flow restrictors, low-flow shower heads, low-flush or composting toilets, grey water systems, and on-site sewage treatment are just a few examples. A publication for those interested in minimizing pollution is entitled, "Nontoxic, Natural, and Earthwise" by Debra Lynn Dadd. It contains the most comprehensive listing of healthful products available and uses a rating system that indicates both safety and environmental impact. It evaluates air and water filters, biodegradable cleaners, pest controls, gardening supplies, and more. Another publication entitled "Clean and Green" by Annie Berthold Bond is an encyclopedic source of solutions to 485 household problems.

The Virgin Islands is fortunate enough to have two financing mechanisms that encourage the private sector to establish waste management/recycling businesses. The U.S. Small Business Administration Pollution Control Loan Program provides financial assistance to small businesses for the planning, design or installation of a pollution control facility. Another opportunity to lure private companies into the Territory is under section 936 of the United States Internal Revenue Code. U.S. corporations receive federal tax exemption on their profits generated in the Territory for operating sewage, solid waste and water treatment facilities.

It is an important first step in addressing our nonpoint source pollution problems by attending and establishing contacts at a conference such as this. I would like to express my sincere thanks to Joan Harrigan-Farrelly and Janice Hodge for inviting me to be a presenter at this conference. On behalf of Claudette Young-Hinds, Director of the Virgin Islands Energy Office, I extend an invitation to everyone to attend the Florida Solar Energy Center workshops on Oct. 22, 23, 28 and 29, and the First Caribbean Energy Conference and Trade Exposition to be held at Sugar Bay Plantation from Oct. 25 - 28.

HOW YOU CAN REDUCE STORMWATER RUNOFF AND POLLUTION

Leonard Reed

Division of Environmental Protection, Department of Planning and Natural Resources, St. Thomas, United States Virgin Islands 00802

INTRODUCTION

Stormwater runoff occurs as a result of rain events. The runoff of stormwater causes soil erosion and water pollution. Soil erosion and water pollution quite often go hand in hand. Water pollution is manageable through design and conservation practices.

SOURCES OF RUNOFF AND POLLUTION

The sources of runoff and pollution are varied and numerous. They include the following:

o Construction and Development Activities
- land clearing
- erosion and gullying due to improper changes in drainage patterns
- increase in runoff due to additional impermeable surfaces
- changes in peak runoff volumes
- widespread encraochment into gut areas
- filling and development of of flood plains and wetlands
- denuding hillsides for "weed control" and cleanliness

o Agricultual Activities
- nutrient loading from fertilizer use
- pesticide runoff

o Roads, Parking Lots and other impermeable surfaces
- changes in peak runoff volumes
- oil, transmission fluids, radiator coolant, brake fluids and other products from vehicles dripping on to the ground

o Wastewater Treatment
- storm waters that are being routed into sewer systems
- storm water intrusion into sewer systems
- direct discharges of treated wastes from treatment plants into water courses

o Solid Wastes/Dumps
- lack of liners and deposition of dump material below water table

CONTROL OF RUNOFF AND POLLUTION

The control of stormwater runoff and the resulting pollution is well within man's reach. The pollution from stormwater runoff occurs because it requires thinking and money. The following is a list of some of the things that we can do to control stormwater and the pollution it may cause:

o Construction and Development Activities
- The practice of clearing a whole site should be discouraged, only those portions of land that are needed for development should be allowed to be cleared.

- Clearing should not be permitted during the rainy season. The rainy season increases the probability of soil erosion and pollution of the waters of the Virgin Islands.

- Currently Earth Change field inspections are performed only prior to land clearance. A second Earth Change inspection is needed after land clearance and prior to any construction activities.

  A third inspection should be performed at the completion of construction with a final inspection one year after occupancy to determine compliance with the Earth Change Plan and the Earth Change Permit.

- Those areas that are disturbed during land clearing should be immediately mulched and seeded.

- The proper use of silt fencing, diversions such as swales, retention and detention basins should be mandatory in order to preserve the resources of the Virgin Islands.

- Those established or natural drainage patterns should be maintained where at all possible in order not to cause additional soil loss and pollution.

- When and where practicable, the maintenance of the maximum flow of stormwater off site prior to land clearing and development should be maintained during the life of the development.

o Roads, Parking Lots and other impermeable surfaces

- Permeable pavers, green areas for absorbtion, level spreaders should be used to minimize the volume of water that will flow off site during and after a storm. Retention and Detention structures should be the standard for large impermeable sites such as parking lots.

- Regulating restrictive encroachments into our guts appears to be urgently needed as less natural areas are available to detain stormwater runoff.

- Oil Water Separators should be used prior to the discharge of stormwater from impermeable surfaces such as parking lots that can accomodate 50 or more vehicles.

- The need to limit development of flood plains and wetlands is equally important. Flood plains and wetlands naturally lend themselves to retention and detention of stormwater.

o Agricultural Activities

- The use of fertilizers that will be absorbed readily by the leaves of the plants or applied below the surface of the soil should be encouraged. We may limit the use of fertilizers by rotating our crops.

- We may also limit the use of pesticide by crop rotation, the use of pest resistant plants and other natural controls such as predatory insects and repellent plants.

o Wastewater Treatment

- We need to modernize our sewer systems. Our sewer systems allow stormwater to intrude thereby causing water pollution as they over-flow. The intentional routing of stormwater into the sewer systems should be discouraged. The construction of the Mangrove Logoon treatment plant shoild be accelerated. This single plant will eliminate 5 sewage treatment plants.

o Solid Wastes/Dumps

- The hardest stormwater related problem to solve is that of the solid wastes facilities in our islands. The damage has been done and therefore use of liners and stopping the practice of placing dump material below water table is not practical for existing facilities. All future permit for solid waste sites will require liners and design to control stormwater.

In conclusion, stormwater and the its resulting pollution are controlable. We must therefore dedicate ourselves to improve our environment by all means of pollution prevention.

HOW TO ESTIMATE STORMWATER RUNOFF IN SMALL WATERSHEDS

MARIO A. MORALES

United States Department of Agriculture
Soil Conservation Service
Resource Conservation & Development
United States Virgin Islands Field Office
St. Croix, USVI 00851

Precipitation is the potential source of stormwater runoff in all watersheds. But precipitation alone does not determine the amount of stormwater runoff that may occur. Other factors important to estimating stormwater runoff include: peak discharge, size of the watershed, soils, hydrologic conditions and topography. Each plays a very important part in stormwater runoff and if we are to estimate the amount of stormwater runoff that may occur, all factors must be considered. Most of the information that I will be presenting today is available in Chapter Two of the USDA Soil Conservation Service Engineering Field Manual.

First, we probably need to understand why we need to know how to estimate the amount of stormwater runoff. Estimating stormwater runoff is required information before any type of soil and water conservation practice or stormwater runoff control measure is implemented. The need to determine the adequate size a structure is required, before a detention pond, a diversion, a drop structure or any other stormwater runoff controlling structure is designed and constructed. Stormwater runoff estimates provide us with a starting point for structural design.

Let us look at the, above mentioned, factors individually. Peak discharge is the peak rate of runoff from a particular drainage area for a given rainfall. Peak discharge is usually caused by intense rainfall. This information is available in a synthesized form (Figures 1 & 2). Rather then having to use different rainfall intensities for each drainage area, 24-hour storm charts have been developed. There are four different types of 24-hour storm distributions. The 24-hour storm charts were developed by the Soil Conservation Service from U.S. National Weather Service data for typical storms. The developed storm charts are associated to climatic regions. This information includes short-duration intensities with those of longer duration. In the Virgin Islands, our storms are classified as Type II storms. The Type II storm is the most intense short duration rainfall classification.

The size of the watershed is important because it provides us with a potential idea of the amount of runoff. The larger the watershed, the larger the potential for greater amounts of stormwater runoff and higher peak discharges. Determining the size of a watershed can be accomplished by actual measurement. But, normally it is measured off of a map, after the watershed has been plotted. The easiest method to determine the area is by planimeter. What a planimeter does is measure the square inches of the plotted watershed. That figure is then multiplied by the coefficient for that scale of map. Other methods may be used, but measurement by planimeter is the most common.

Soils are also important in estimating stormwater runoff (Figure 3). Soil texture and inclusions are relevant to the permeability and infiltration rates, as well as surface intake rates. Soils have been classified into four Hydrologic Soil Groups (A, B, C and D). Group A consists of soils with high infiltration rates, even when wet. Please notice that there are no soils in the Virgin Islands that are in Group A. (Figure 4) Group B consists of soils that have moderate infiltration rates when wet. Group C consists of soils with low infiltration rates when wet. Group D consists of soils with very slow infiltration rates when wet.

Hydrologic conditions on most sites affect the volume of runoff more then any other single factor. Hydrologic conditions are a combination of vegetative cover and conservation practice influences (Figure 5). Any soil disturbance can significantly affect infiltration rates. Urbanization (Figure 6) effects runoff rates because impervious surfaces increase runoff rates, very little to no infiltration occurs.

Curve Numbers have been developed by examining rainfall runoff. This Curve Number index is of runoff potential depending on specific conditions.

Vegetative cover is important in estimating runoff. Vegetation and "litter" maintain soil infiltration potential by limiting the impact of raindrops on the soil surface. Vegetation also slows the rate at which runoff travels across the land and allows additional time of concentration. Vegetation also reduces peak discharge.

Established conservation practices are also important in estimating runoff and peak discharge. Mechanical practices such as contour farming and terracing and/or management practices such as crop rotations and no or reduced tillage allow for additional soil infiltration potential. By slowing the rate at which runoff travels and increasing the time of concentration stormwater runoff maybe reduced. Cultivated land, although easier to be dislodged, also increases the soil infiltration potential.

Topography affects stormwater runoff and peak discharge. The slopes of a watershed have a major impact on runoff velocity and time of concentration, thus affecting soil infiltration rates. Additionally, we all know that in most cases the steeper the slopes, the shallower the soil profile, which affects soil water holding capacity.

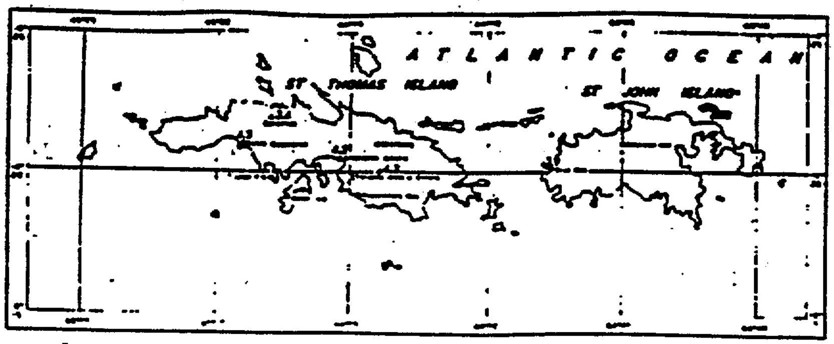
Stormwater runoff is expressed in inches. Or rather in average depth of water that would cover the entire watershed. The volume of runoff is computed by converting the depth over the entire watershed to volume and is usually expressed in acre-feet. When the Curve Number and rainfall have been determined for the watershed, runoff can then be determined by using Figure 8.

As we have seen, many factors affect stormwater runoff. By taking these factors into account and using the technical knowledge that is available, we can estimate stormwater runoff in small watersheds. By using this information and applying it at the design stage of a development, we could minimize the effects of stormwater runoff. Proper planning, design, and construction is much more cost effective when done correctly the first time. The costs of correcting a poor plan, design and/or construction can be enormous. Estimating stormwater runoff is essential to proper planning, design, and construction.

References: USDA Soil Conservation Service - Technical Bulletin 55, Urban Hydrology for Small Watersheds. June 1986.

USDA Soil Conservation Service - Agriculture Handbook Number 590, Ponds-Planning, Design, Construction. June 1982.

USDA Soil Conservation Service - Engineering Field Manual Chapter 2: Estimating runoff and peak discharges. Revised.



Precipitation values for the U.S. Virgin Islands - 2-year 24-hour rainfall (inches)

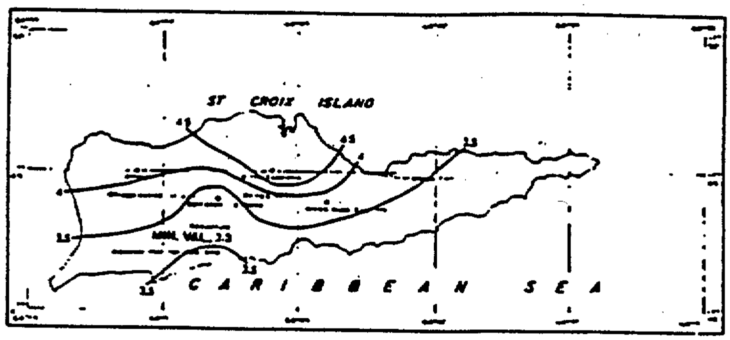
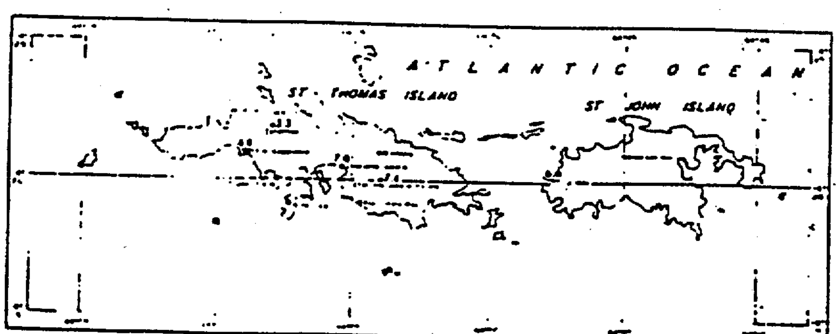
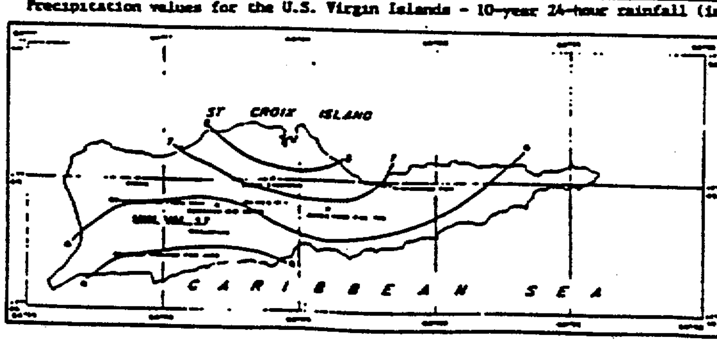
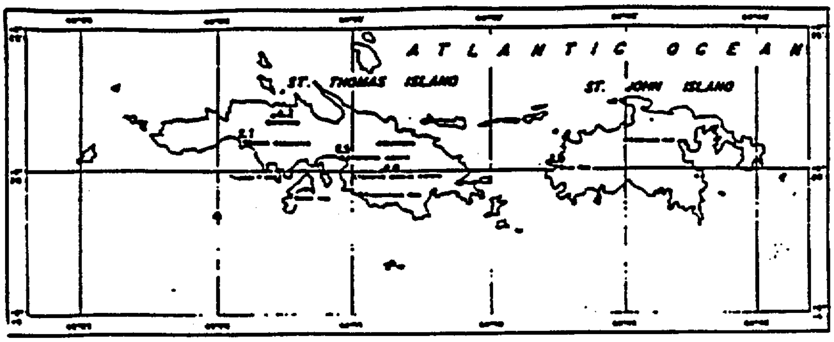


Figure 1



Precipitation values for the U.S. Virgin Islands - 10-year 24-hour rainfall (inches)





Precipitation values for the U.S. Virgin Islands - 25-year 24-hour rainfall (inches)

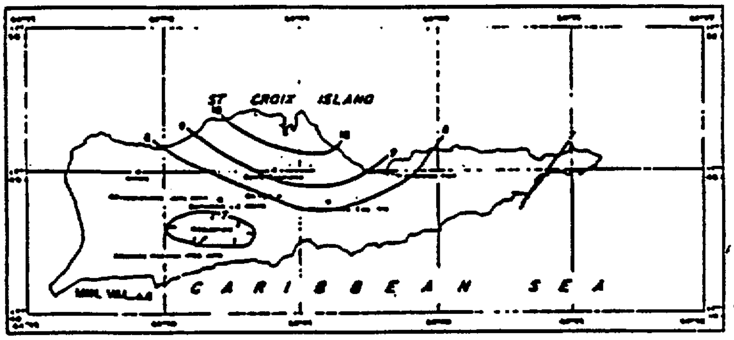
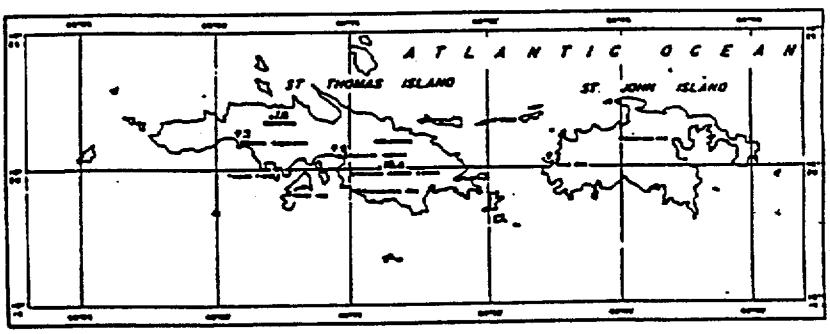
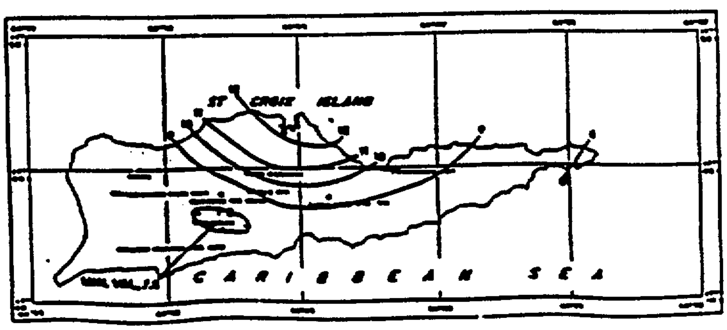


Figure 2



Precipitation values for the U.S. Virgin Islands - 50-year 24-hour rainfall (inches)



HYDROLOGIC SOIL GROUPS
PUERTO RICO - VIRGIN ISLANDS

Revised March 1972 — Figure 3

A	B	C	D
Aguadilla	Aceitunas	Adjuntas	Aguirre
Arenales	Aguilita	Aibonito	Bajura
Cataño	Alonso	Anones	Caguabo
Cuyon	Amelia	Cabo Rojo	Camaguey
Espinal	Bayamón	Callabo	Cartagena
Jaucas	Bejucos	Candelero	Ciales
Meros	Caribe	Cayaguá	Cintrona
Reilly	Catalina	Cidral	Coloso
Río Lajas	Colinas	Coamo	Constancia
	Comerío	Córcega	Cramer
	Consumo	Corozal	Cuchillas
	Cornhill	Cotito	Descalabrado
	Cortada	Coto	Diamond
	Delicias	Daguao	Fe
	Dique	Daguey	Fortuna
	Ensenada	Dorothea	Fraternidad
	Guamaní	Fajardo	Guánica
	Guanábano	Fredensborg	Guayabota
	Guayabo	Glynn	Guayama
	Humacao	Guanajibo	Gurabo
	Jacaguas	Guerrero	Hesselberg
	Jagueyes	Ingenio	Igualdad
	Juana Díaz	Isaac	Jaçana
	Lavallee	Jobos	Juncos
	Limaní	Juncal	Mabí
	Limones	Junquitos	Machuelo
	Lirios	Lares	Maguayo
	Magens	Llanos	Malaya
	Maleza	Los Guineos	Maunabo
	Maraguez	Machete	Moca
	Maresua	Maní	Montegrande
	Maricao	Mariana	Múcara
	Matanzas	Morado	Pandura
	Mayo	Naranjito	Parcelas
	Nipe	Naranjo	Paso Seco
	Parasol	Palmarejo	Perchas
	Patillas	Picacho	Piñones
	Pellejas	Quebrada	Ponceña
	Plata	Rosario	Reparada
	Pozo Blanco	Santa Clara	Río Arriba
	Río Piedras	Santa Marta	Sabana
	San Antón	Humatas	

Hydrologic soil groups

Soils have been classified into four hydrologic soil groups as shown in table 2-1. The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of sands and gravels that are deep, well drained to excessively drained, and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of soils that are moderately deep to deep, moderately well drained to well drained, and have moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils having a layer that impedes downward movement of water and soils of moderately fine to fine texture. These soils have a slow rate of water transmission (0.05 to 0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr).

Figure 4

Figure 5

—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—		
Cover type	Hydrologic condition	A	B	C
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86
	Fair	49	69	79
	Good	39	61	74
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77
	Fair	35	56	70
	Good	[4]30	48	65
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82
	Fair	43	65	76
	Good	32	58	72
Woods.[6]	Poor	45	66	77
	Fair	36	60	73
	Good	[4]30	55	70
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82

[1]Average runoff condition, and $I_a = 0.2S$.

Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

Poor: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

Actual curve number is less than 30; use CN = 30 for runoff computations.

CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be com[illegible] om the CN's for woods and pasture.

Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Figure 6

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2a).					

[1] Average runoff condition.

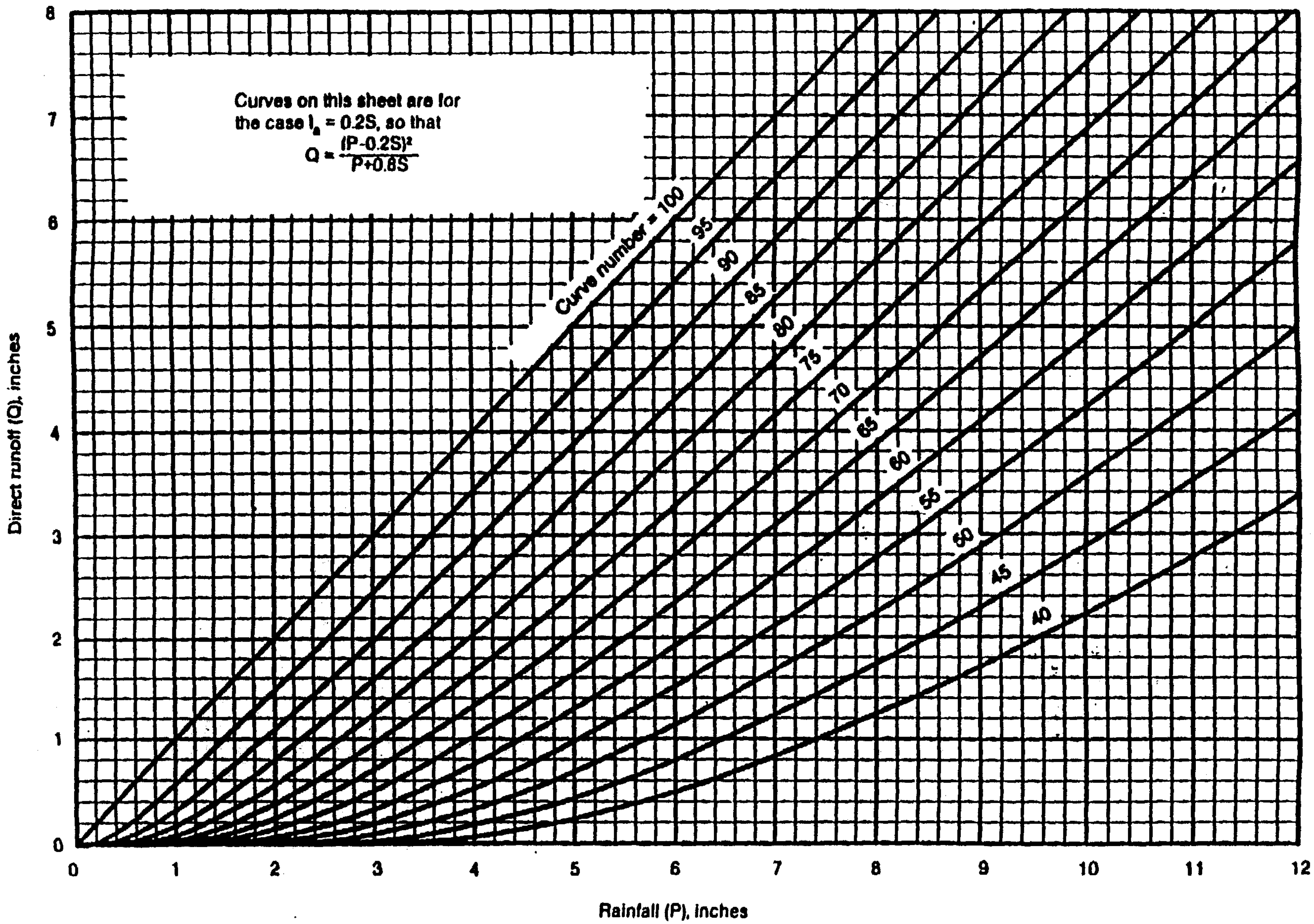
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed based on the impervious area (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Figure 7



—Solution for runoff equation

STRUCTURAL PRACTICES TO CONTROL STORMWATER RUNOFF

Warner A. Irizarry, PE

United State Department of Agriculture
Soil Conservation Service
Caribbean Area
P.O. Box 364868
San Juan, Puerto Rico 00936-4868

Roof Runoff Management (No.)

Definition

A facility for collecting, controlling, and disposing of runoff water from roofs.

Scope

This standard establishes the minimally acceptable requirements for design, construction, and operation of roof management facilities. Such facilities include but are not limited to erosion-resistant channels or subsurface drains with rock-filled trenches along building foundations below eaves, roof gutters, downspouts, and appurtenances.

Purpose

To prevent roof runoff water from flowing across concentrated waste areas, barnyards, roads and alleys, and to reduce pollution and erosion, improve water quality, prevent flooding, improve drainage, and protect the environment.

Conditions where practice applies

This practice applies where: (1) a roof runoff management facility is included in an overall plan for a waste management system; (2) roof runoff water may come in contact with wastes or cause soil erosion; and (3) barnyard flood protection or improved drainage is needed.

Design criteria

Capacity. Design of roof runoff management facilities shall be based on the runoff from a 10-year frequency, 5-minute rainfall except that a 25-year frequency, 5-minute rainfall shall be used to design such facilities for exclusion of roof runoff from waste treatment lagoons, waste storage ponds, or similar practices. Rainfall from figures 1 and 2 or reliable local records may be used for design.

Materials. Roof gutters and downspouts may be made of aluminum, galvanized steel, wood, or plastic. Aluminum gutters and downspouts shall have a nominal thickness of at least 0.07 and 0.05 cm, (0.027 and 0.020 in), respectively. Galvanized steel gutters and downspouts shall be at least 28 gage. Wood shall be clear and free of knots. A water-repellent preservative shall be applied to the flow area of wood other than redwood, cedar, or cypress. Plastics shall contain ultraviolet stabilizers. Dissimilar metals shall not be in contact with each other.

Supports. Gutter supports shall have sufficient strength to withstand anticipated water, snow, and ice loads. They shall have a maximum spacing of 120 cm (48 in) for galvanized steel and 81 cm (32 in) for aluminum or plastic. Wood gutters shall be mounted on fascia boards using furring blocks that are a maximum of 61 cm (24 in) apart. Downspouts shall be securely fastened at the top and bottom with intermediate supports that are a maximum of 3 m (10 ft) apart.

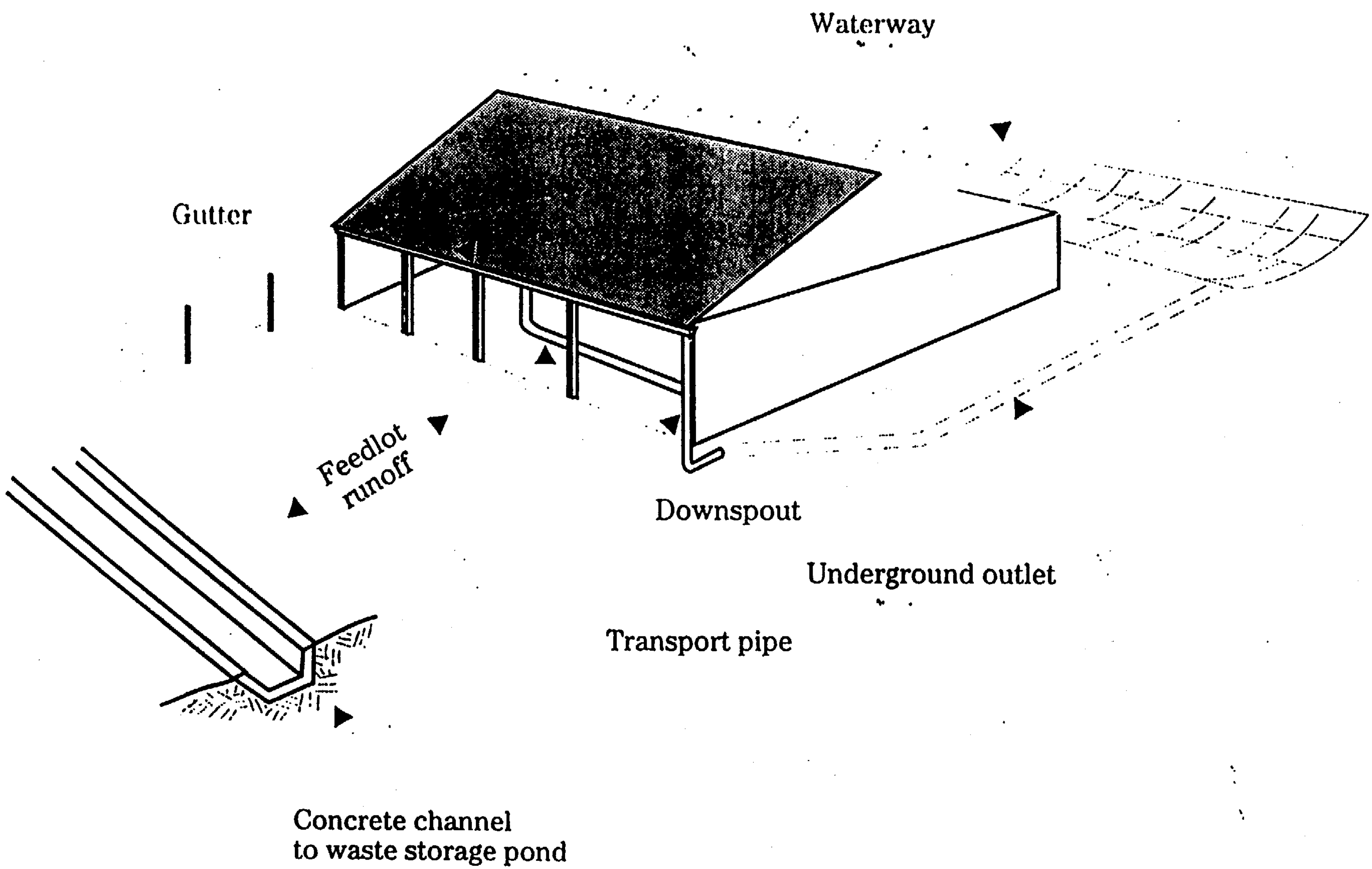
Outlets. The water from roof runoff management facilities may empty into surface drains or underground outlets, or onto the ground surface. When downspouts empty onto the ground surface, there shall be an elbow to direct water away from the building and splash blocks or other protection shall be provided to prevent erosion.

Protection. Roof runoff management facilities and outlets shall be protected from damage by livestock and equipment. Where appropriate, snow and ice guards may be installed on roofs to protect gutters and reduce the hazard to humans and animals below. Gutters may be installed below the projection of the roof line to further reduce gutter damage from snow and ice.

Plans and specifications

Plans and specifications for installing roof runoff management facilities shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Figure 10–1 Roof gutter and downspout

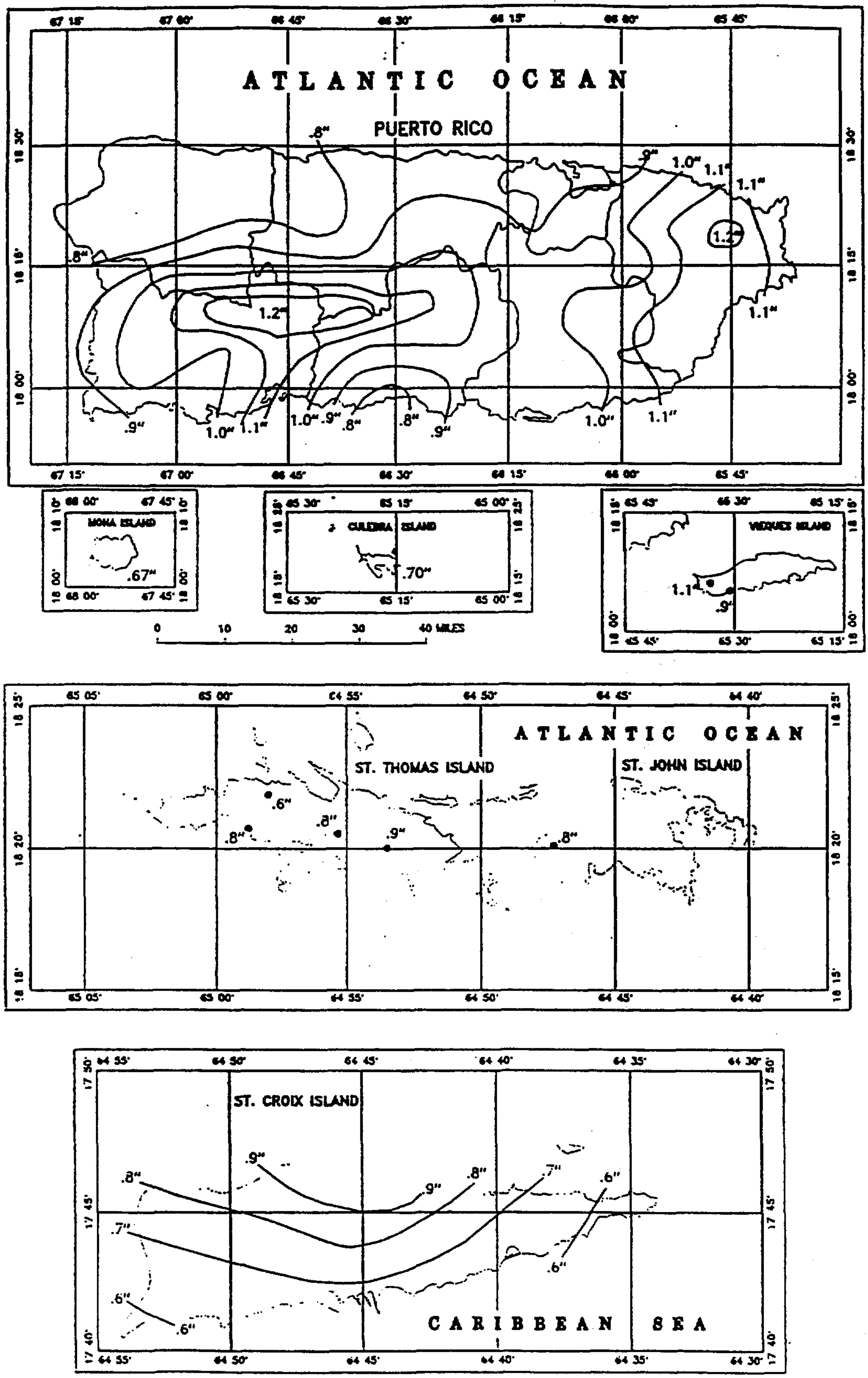


U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

FIGURE 10B-3b

10-YEAR 5-MINUTE RAINFALL (INCHES)



SOURCE:
DATA PROVIDED BY SCS FIELD PERSONNEL.
MAP PREPARED USING AUTOMATED MAP CONSTRUCTION. NATIONAL CARTOGRAPHIC CENTER, FORT WORTH, TEXAS 1991.

APRIL 1991 1005767

Diversion (Ft)

Definition

A channel constructed across the slope with a supporting ridge on the lower side.

Scope

This standard applies to the installation of all diversions except floodwater diversions (400) and diversion dams (348).

Purpose

To divert excess water from one area for use or safe disposal in other areas.

Conditions where practice applies

This practice applies to sites where:

1. Runoff damages cropland, pastureland, farmsteads, feedlots, or conservation practices such as terraces or stripcropping.
2. Surface flow and shallow subsurface flow caused by seepage are damaging sloping upland.
3. Runoff is in excess and available for use on nearby sites.
4. A diversion is required as part of a pollution abatement system.
5. A diversion is required to control erosion and runoff on urban or developing areas and construction or mining sites.

Design criteria

Capacity. Diversions as temporary measures, with a life span of less than 2 years, shall carry as a minimum the 2-year, 24-hour-duration storm. Diversions that protect agricultural land and those that are part of a pollution abatement system must have the capacity to carry the peak runoff from a 10-year-frequency, 24-hour-duration storm as a minimum.

Diversions designed to protect areas such as urban areas, buildings, and roads, shall have enough capacity to carry the peak runoff expected from a storm frequency consistent with the hazard involved but not less than a 25-year-frequency, 24-hour-duration storm with a freeboard not less than 0.3 ft.

Cross section. The channel may be parabolic, V-shaped, or trapezoidal. The diversion shall be designed to have stable side slopes. The ridge height shall include an adequate settlement factor. The ridge shall have a minimum top width of 4 ft at the design elevation. The minimum cross section shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified overfill for settlement.

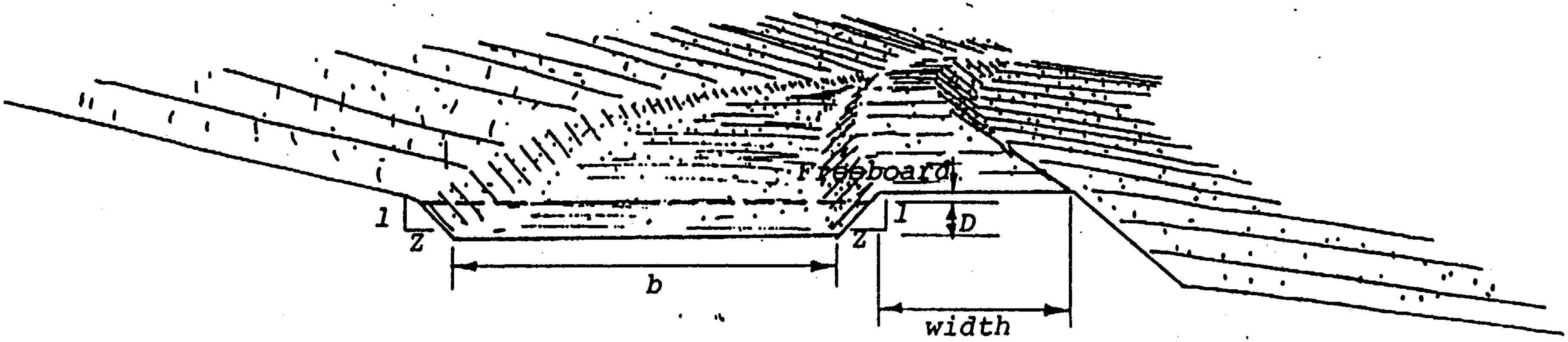
Grade and velocity. Channel grades may be uniform or variable. Channel velocity shall not exceed that considered nonerosive for the soil and planned vegetation or lining.

Location. The location of the diversion shall be determined by outlet conditions, topography, land use, cultural operations, and soil type. A diversion in a cultivated field must be aligned to permit use of modern farming equipment.

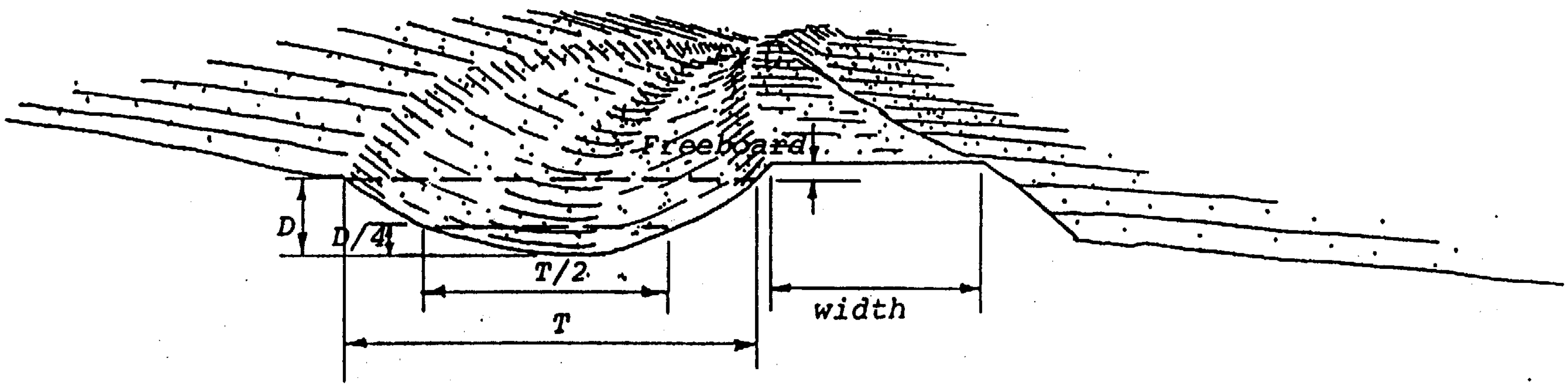
Protection against sedimentation. Diversions should not be used below high-sediment-producing areas unless land treatment practices or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions. If movement of sediment into the channel is a significant problem, a vegetated filter strip shall be used where soil or climate does not preclude its use. Then, the design shall include extra capacity for sediment and be supported by supplemental structures, cultural or tillage practices, or special maintenance measures.

Outlets. Each diversion must have a safe and stable outlet with adequate capacity. The outlet may be a grassed waterway, a vegetated or paved area, a grade stabilization structure, an underground outlet, a stable watercourse, or a combination of these practices. The outlet must convey runoff to a point where outflow will not cause damage. Vegetative outlets shall be installed before diversion construction to insure establishment of vegetative cover in

DIVERSION



TRAPEZOIDAL CROSS-SECTION



PARABOLIC CROSS-SECTION

DIVERSION DIKE

Definition

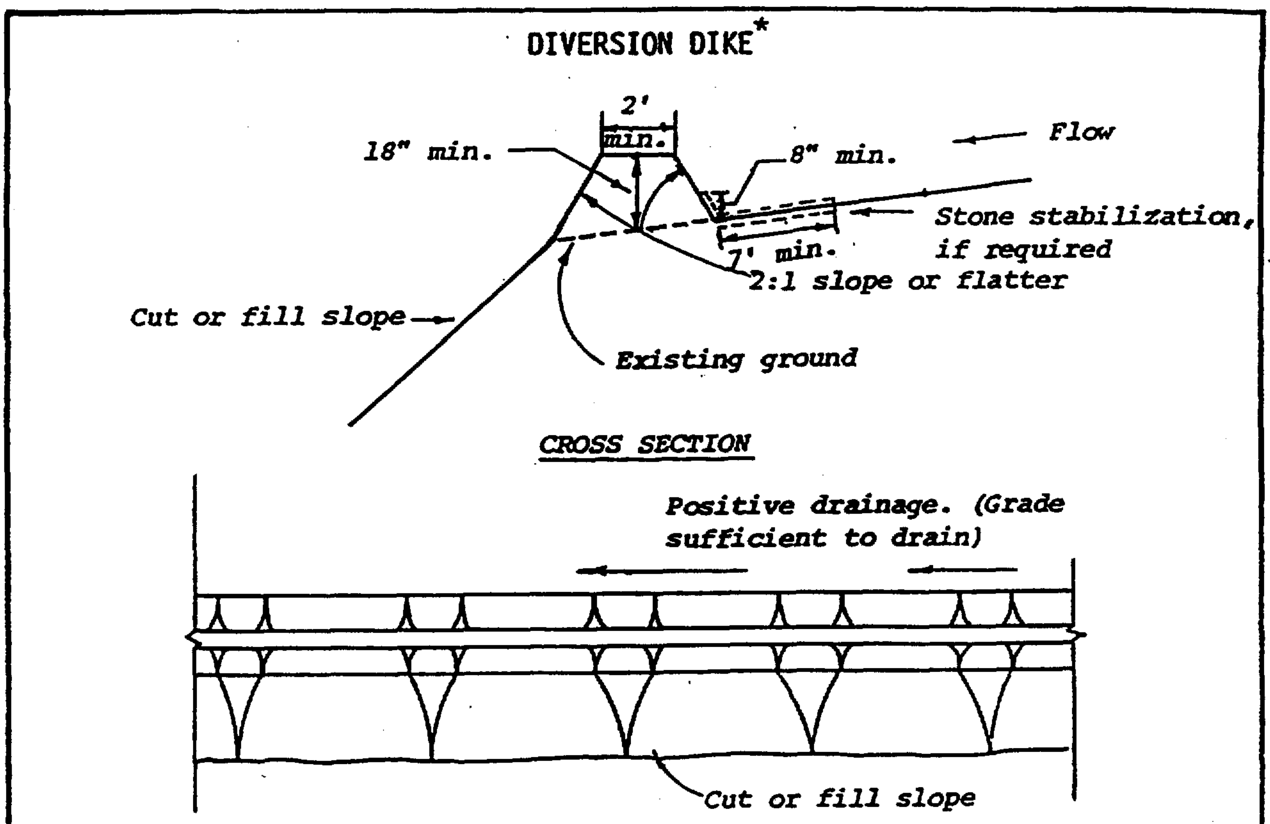
A temporary ridge of compacted soil immediately above cut or fill slopes and constructed with sufficient grade to provide drainage.

Purpose

The purpose of a diversion dike is to intercept storm runoff from small upland areas and divert it from exposed slopes to an acceptable outlet.

Conditions Where Practice Applies

The diversion dike is used for the period of construction at the top of newly constructed slopes to prevent excessive erosion until permanent drainage features are installed and/or slopes are stabilized.



INTERCEPTOR DIKE

Definition

A temporary ridge of compacted soil, located across disturbed areas or rights-of-way.

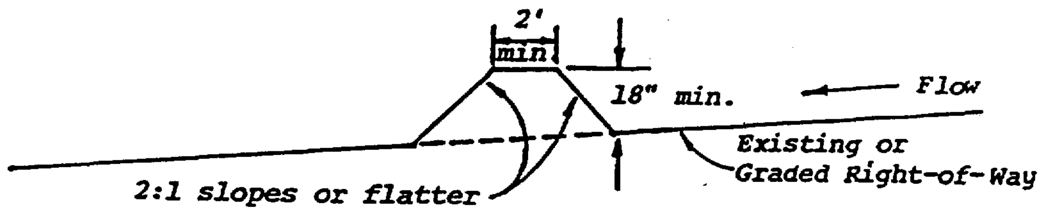
Purpose

The purpose of an interceptor dike is to shorten the length of exposed slopes, thereby reducing the potential for erosion, by intercepting storm runoff and diverting it to a stabilized outlet or sediment trapping device.

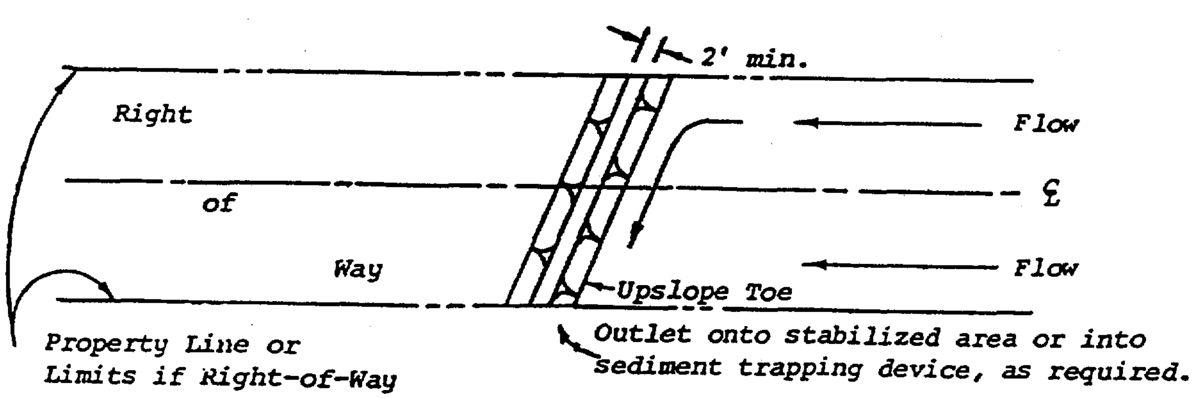
Conditions Where Practice Applies

Interceptor dikes are constructed across disturbed rights-of-way such as for pipe lines and streets or disturbed areas such as graded parking lots or landfills. The dikes shall remain in place until the disturbed areas are permanently stabilized.

INTERCEPTOR DIKE*
(not to scale)



CROSS SECTION



PLAN VIEW

USDA-Soil Conservation Service

STANDARD AND SPECIFICATIONS

FOR

PERIMETER DIKE

Definition

A temporary ridge of compacted soil located along the perimeter of the site or disturbed areas.

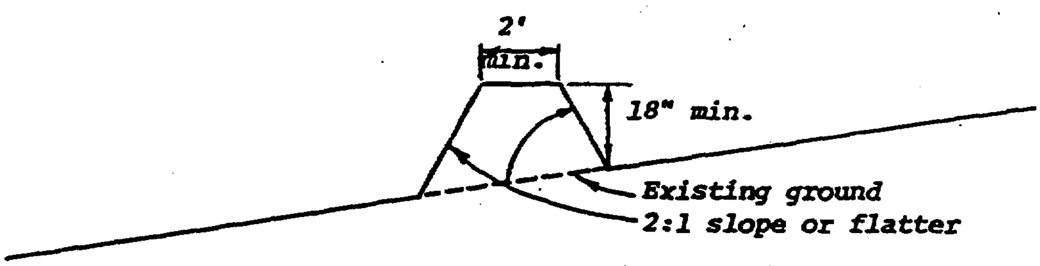
Purpose

The purpose of a perimeter dike is to prevent offsite storm runoff from entering the disturbed area and to prevent sediment laden storm runoff from leaving the construction site or disturbed area.

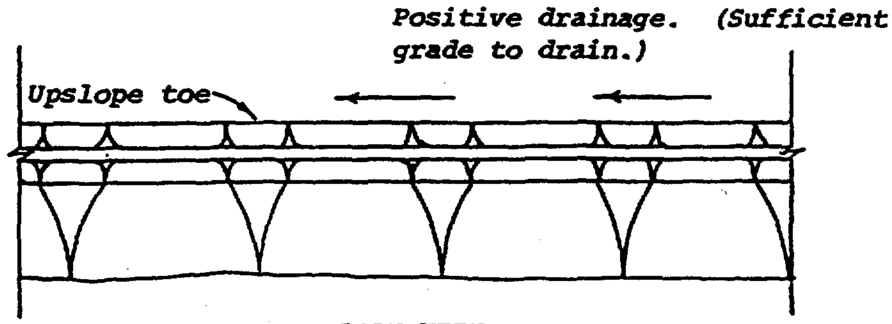
Conditions Where Practice Applies

The perimeter dike is used for the period of construction at the perimeter of the disturbed area to transport sediment laden water to a sediment trapping device such as a sediment trap or sediment basin. This dike shall remain in place until the disturbed area is permanently stabilized. The storm runoff prevented from entering the disturbed area by the perimeter dike shall be adequately handled to prevent damage due to flooding or erosion to adjacent property.

PERIMETER DIKE*
(not to scale)



CROSS SECTION



PLAN VIEW

INTERCEPTOR SWALE

Definition

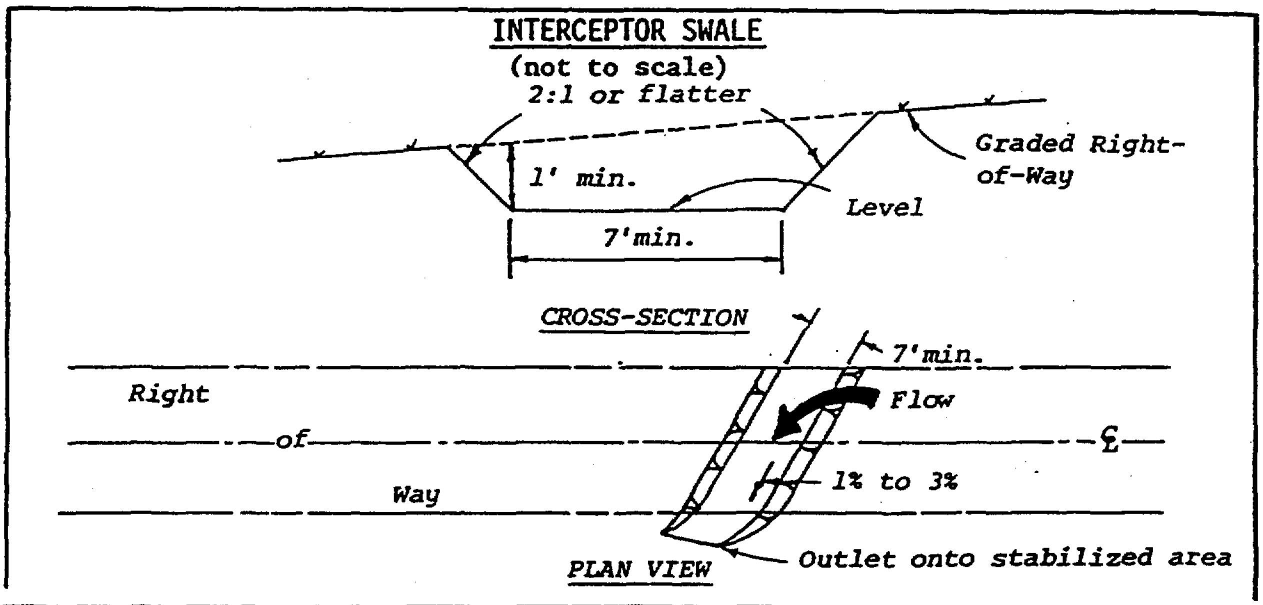
A temporary excavated drainageway located across disturbed areas or rights-of-way.

Purpose

The purpose of an interceptor swale is to shorten the length of exposed slopes, thereby reducing the potential for erosion, by intercepting storm runoff and diverting it to a stabilized outlet or sediment trapping device.

Conditions Where Practice Applies

Interceptor swales are constructed across disturbed rights-of-way such as for pipe lines and streets or disturbed areas such as graded parking lots or land fills. The swale shall remain in place until the disturbed areas are permanently stabilized.



PERIMETER SWALE

Definition

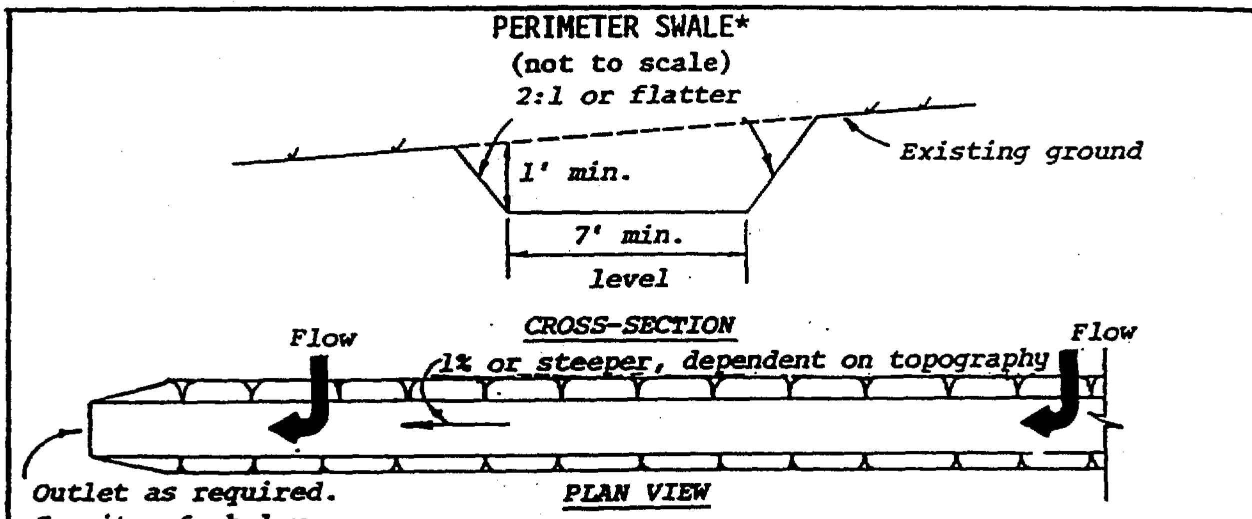
A temporary excavated drainageway located along the perimeter of the site or disturbed areas.

Purpose

The purpose of a perimeter swale is to prevent offsite storm runoff from entering the disturbed area and to prevent sediment laden storm runoff from leaving the construction site or disturbed area.

Conditions Where Practice Applies

The perimeter swale is used for the period of construction at the perimeter of the disturbed area to transport sediment laden water to a sediment trapping device such as a sediment trap or sediment basin. This swale shall remain in place until the disturbed area is permanently stabilized. The perimeter swale also is used to prevent storm runoff from entering the disturbed area. This runoff shall be adequately handled to prevent damage due to flooding or erosion to adjacent property.



Construction Specifications

Grassed Waterway (Acre)

Definition

A natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff.

Scope

This standard applies to natural or constructed channels that are to be established to vegetation and used for water disposal. Grassed waterways with stone centers are also included.

Purpose

To convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality.

Conditions where practice applies

All sites where added capacity, vegetative protection, or both are required to control erosion resulting from concentrated runoff and where such control can be achieved by using this practice alone or combined with other conservation practices. This practice is not applicable where its construction would destroy important woody wildlife cover and the present watercourse is not seriously eroding.

Planning considerations

The most critical time in successfully installing grassed waterways is when vegetation is being established. Special protection such as mulch anchoring, straw or hay bale dikes, or other diversion methods are warranted at this critical period. Supplemental irrigation may also be warranted. The vegetation should be well established before large flows are permitted in the channel.

Design criteria

Capacity. The minimum capacity shall be that required to convey the peak runoff expected from a storm of 10-year frequency, 24-hour duration. When slope is less than 1 percent, out-of-bank flow may be permitted if such flow will not cause excessive erosion. The minimum in such cases shall be the capacity required to remove the water before crops are damaged.

Velocity. Design velocities shall not exceed those obtained by using the procedures, "n" values, and recommendations in the Engineering Field Manual or SCS-TP-61, Handbook of Channel Design for Soil and Water Conservation.

Width. The bottom width of trapezoidal waterways shall not exceed 100 ft unless multiple or divided waterways or other means are provided to control meandering of low flows.

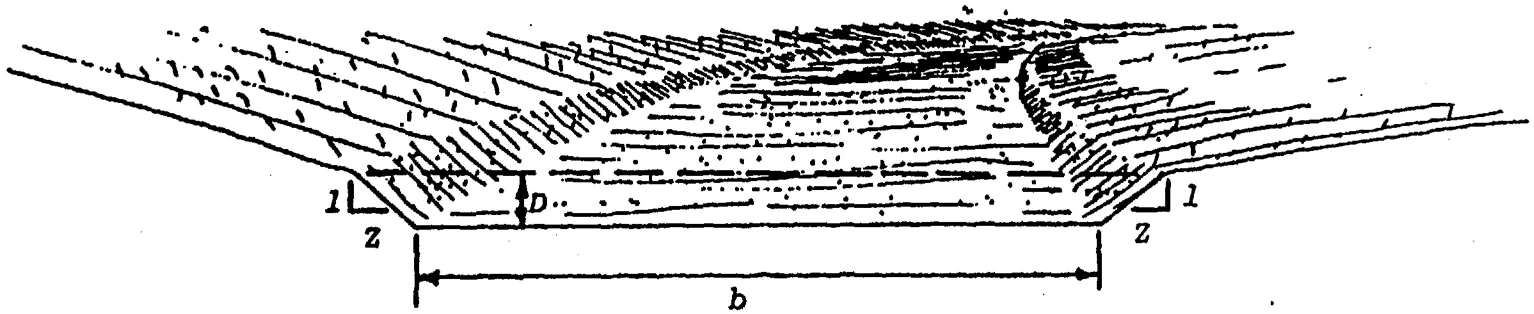
Side slopes. Side slopes shall not be steeper than a ratio of two horizontal to one vertical. They should be designed to accommodate the land user's equipment.

Depth. The minimum depth of a waterway that receives water from terraces, diversions, or other tributary channels shall be that required to keep the design water surface elevation at, or below, the design water surface elevation in the terrace, diversion, or other tributary channel at their junction when both are flowing at design depth.

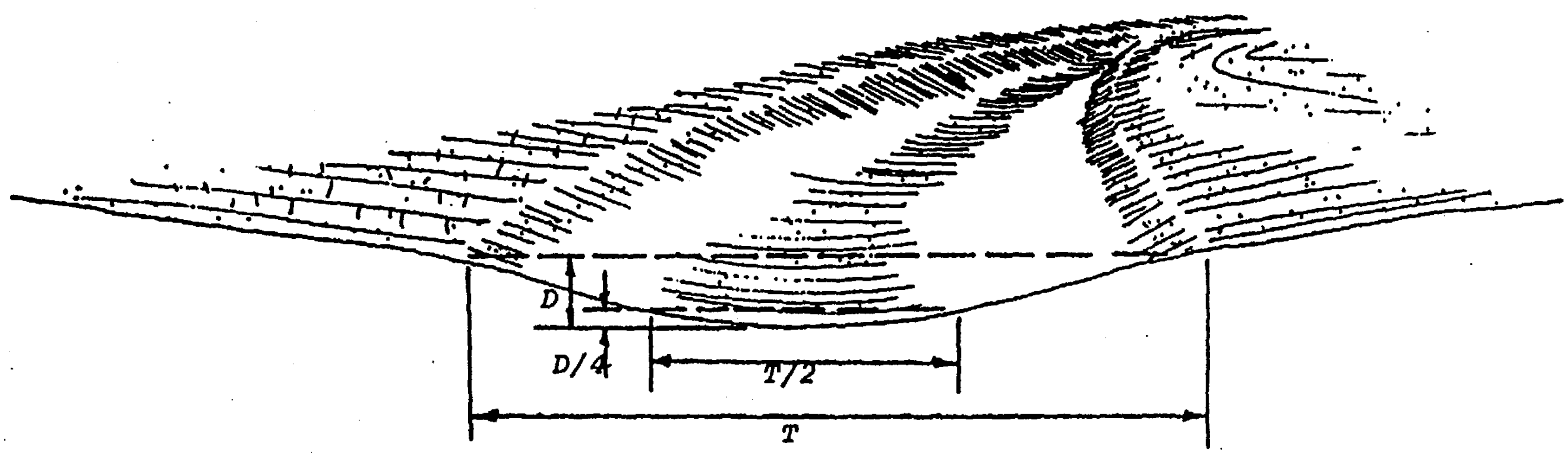
Drainage. Subsurface drains (606), underground outlets (620), stone center waterways, or other suitable measures shall be provided for in the design for sites having prolonged flows, a high water table, or seepage problems. Water-tolerant vegetation such as reed canarygrass may be an alternative on some wet sites.

Outlets. All grassed waterways shall have a stable outlet with adequate capacity to prevent ponding or flooding damages. The outlet can be another vegetated channel, an earth ditch, a grade stabilization structure, or other suitable outlets.

GRASSED WATERWAY



TRAPEZOIDAL CROSS-SECTION



PARABOLIC CROSS-SECTION

USDA-Soil Conservation Service

STANDARD AND SPECIFICATIONS

FOR

LEVEL SPREADER

Definition

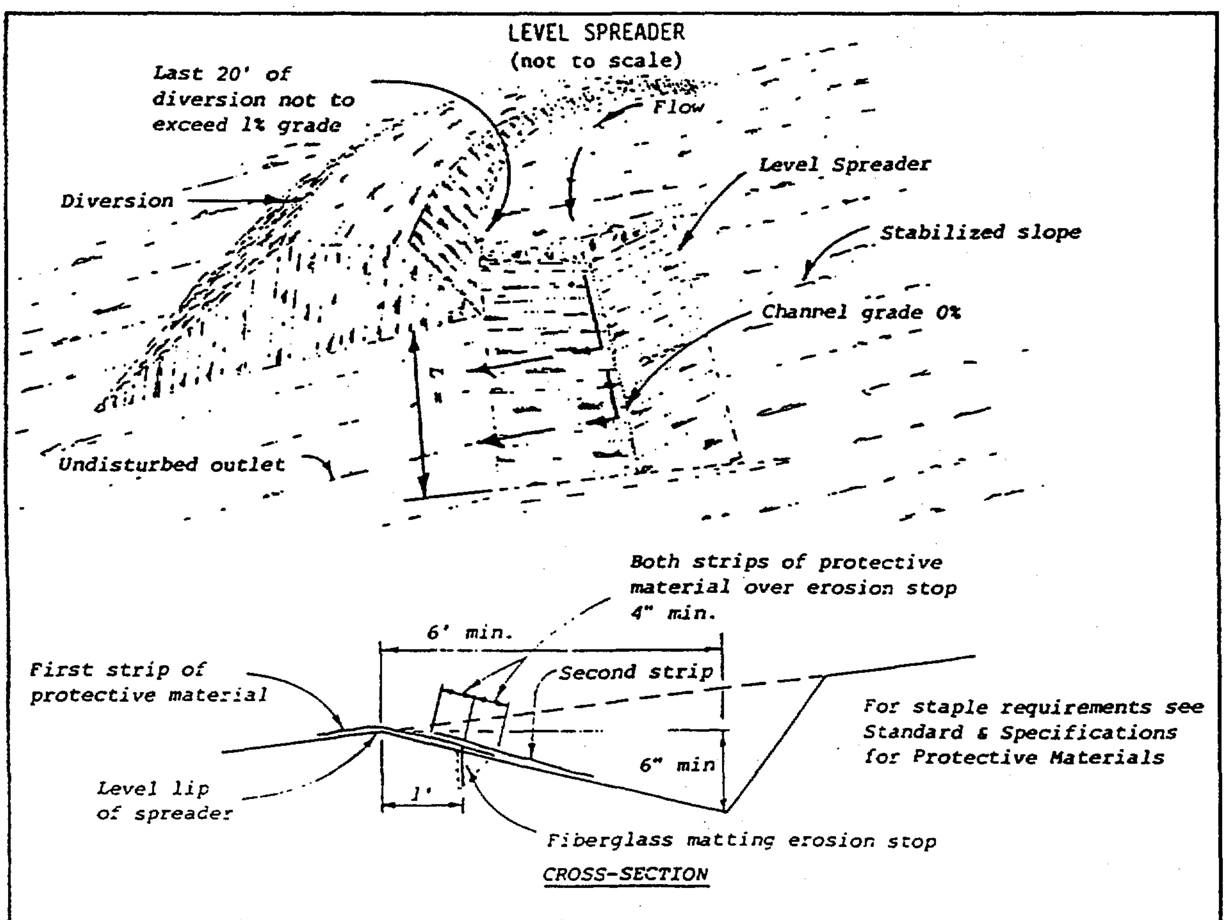
An outlet constructed at zero percent grade across the slope whereby concentrated runoff may be discharged at non-erosive velocities onto undisturbed areas stabilized by existing vegetation.

Purpose

The purpose of the level spreader is to convert a concentrated flow of sediment-free runoff (e.g. diversion outlets) into sheet flow and to outlet it onto areas stabilized by existing vegetation without causing erosion.

Conditions Where Practice Applies

The level spreader is used only in those situations where the spreader can be constructed on undisturbed soil, where the area directly below the level lip is stabilized by existing vegetation, where the drainage area above the spreader is stabilized by existing vegetation, and where the water will not be reconcentrated immediately below the point of discharge.



STONE OUTLET STRUCTURE

Definition

A temporary crushed stone dike installed in conjunction with and as a part of a diversion dike, interceptor dike, or perimeter dike.

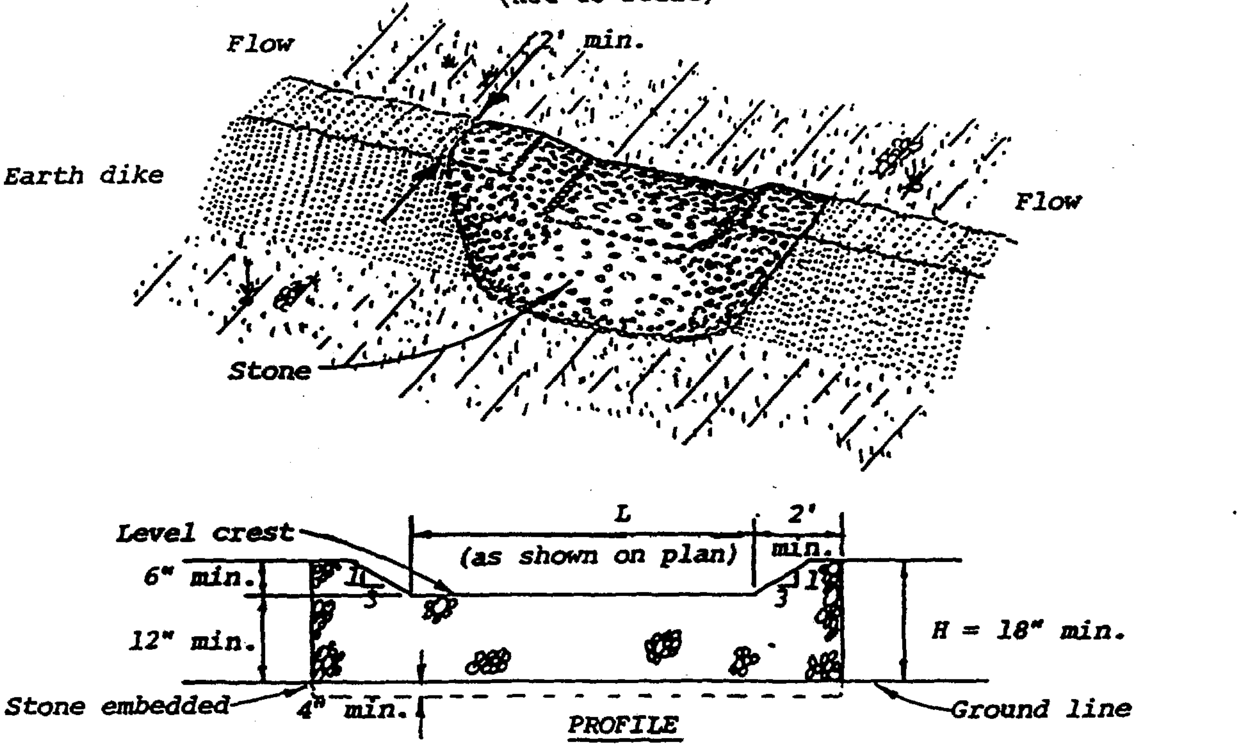
Purpose

The purpose of the stone outlet structure is to provide a protected outlet for a diversion dike, interceptor dike, or perimeter dike, to provide for diffusion of concentrated flow, and to allow the area behind the dike to dewater.

Conditions Where Practice Applies

Stone outlet structures apply to any point of discharge where there is need to dispose of runoff at a protected outlet or to diffuse concentrated flow for the duration of the period of construction. When the entire drainage area to the structure is not stabilized, a sediment trap must be provided in conjunction with the stone outlet structure (See Standard and Specifications for Sediment Trap).

STONE OUTLET STRUCTURE*
(not to scale)



(PAVED CHUTE OR FLUME)

Definition

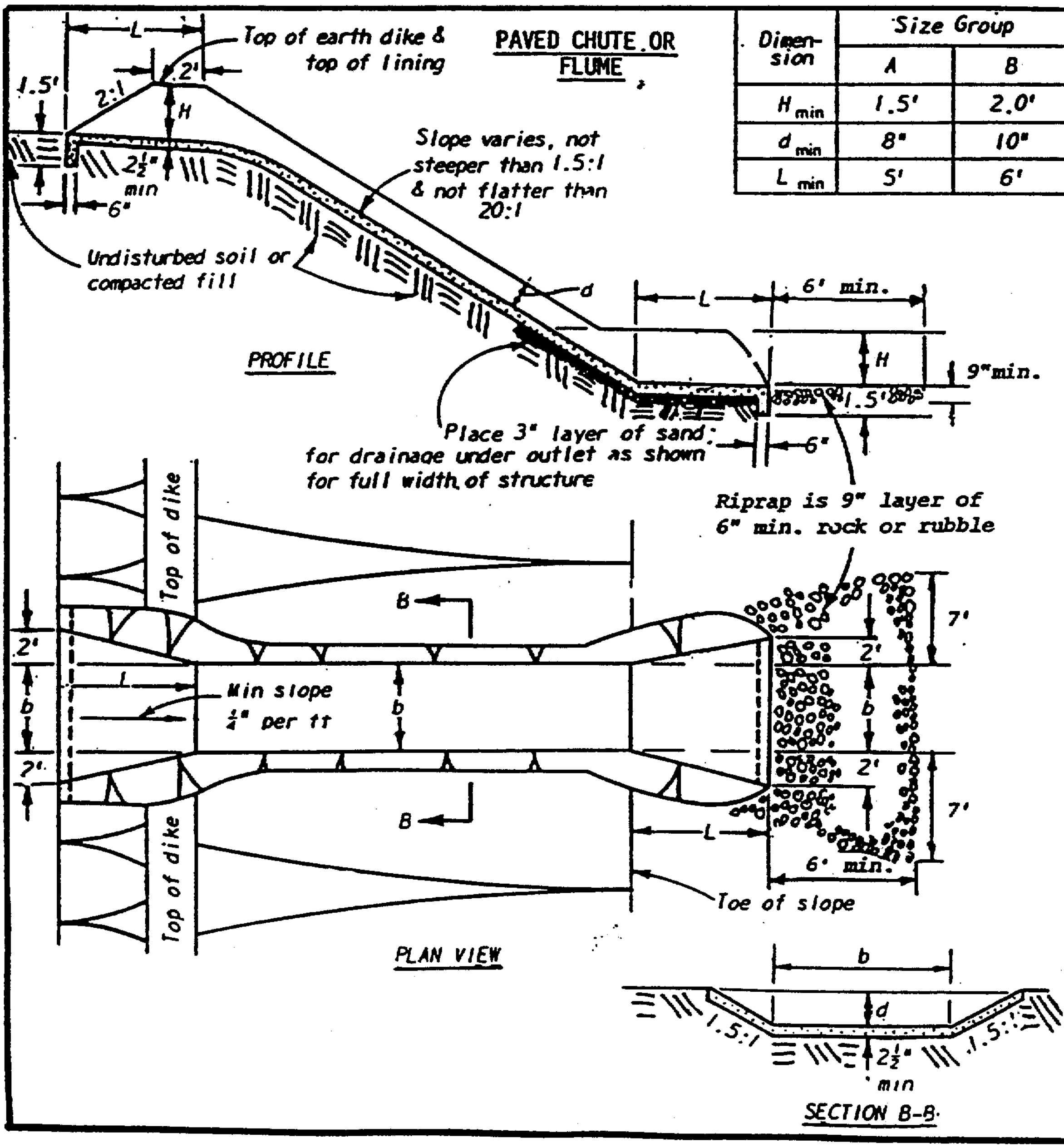
A temporary channel lined with bituminous concrete, portland cement concrete, or comparable non-erodible material placed to extend from the top of a slope to the bottom of a slope.

Purpose

The purpose of the paved chute or flume is to convey surface runoff safely down slopes without causing erosion.

Conditions Where Practice Applies

A paved chute or flume is to be used where concentrated flow of surface runoff must be conveyed down a slope in order to prevent erosion. The maximum allowable drainage area shall be 36 acres.



Dimension	Size Group A	Size Group B
H_{min}	1.5'	2.0'
d_{min}	8"	10"
L_{min}	5'	6'

GRADE STABILIZATION STRUCTURE

(PIPE SLOPE DRAIN)

Definition

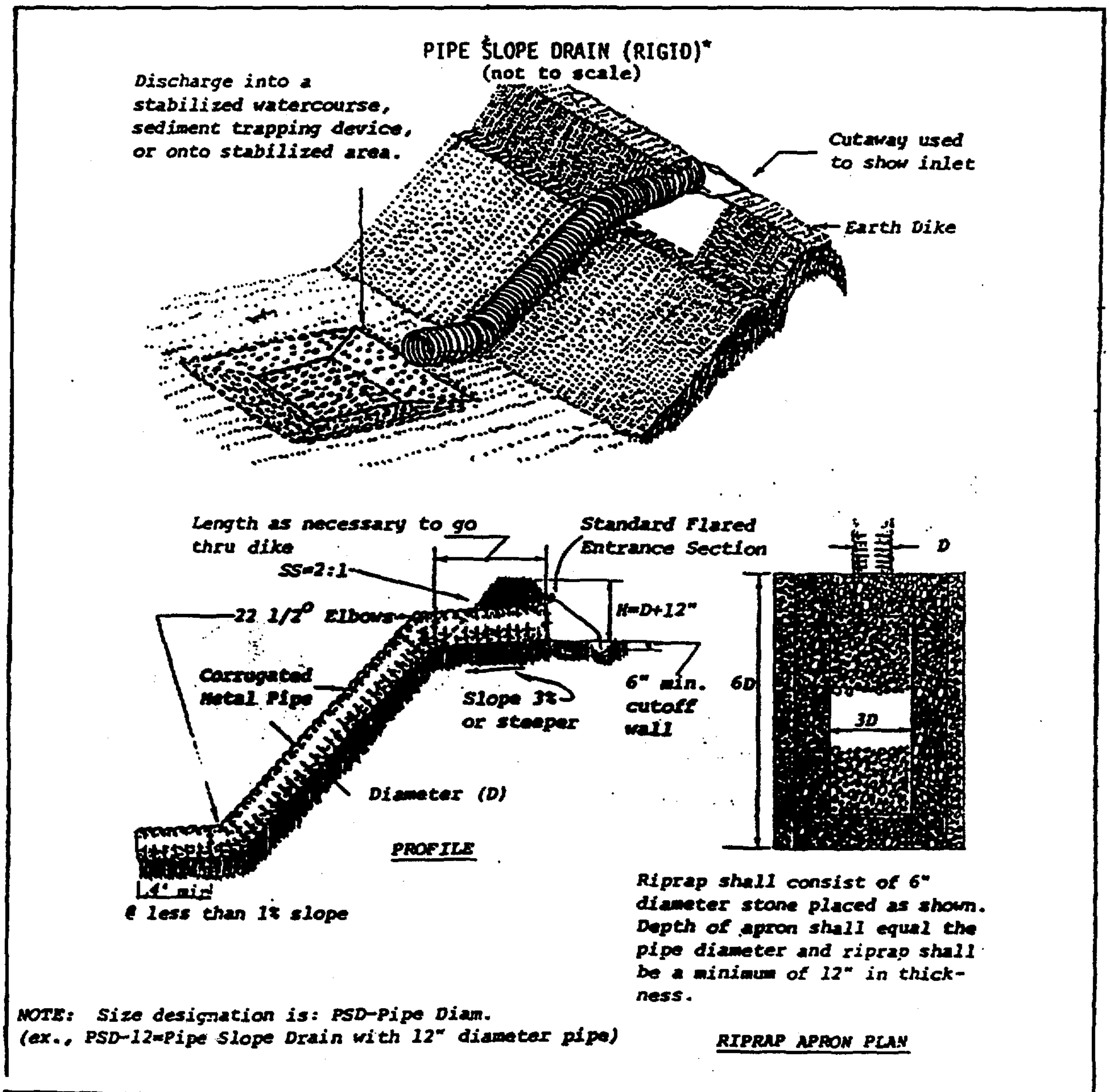
A flexible tubing and/or rigid pipe with prefabricated entrance section temporarily placed to extend from the top of a slope to the bottom of a slope.

Purpose

The purpose of the pipe slope drain is to convey surface runoff safely down slopes without causing erosion.

Conditions Where Practice Applies

Pipe slope drains are to be used where concentrated flow of surface runoff must be conveyed down a slope in order to prevent erosion. The maximum allowable drainage area shall be 5 acres.



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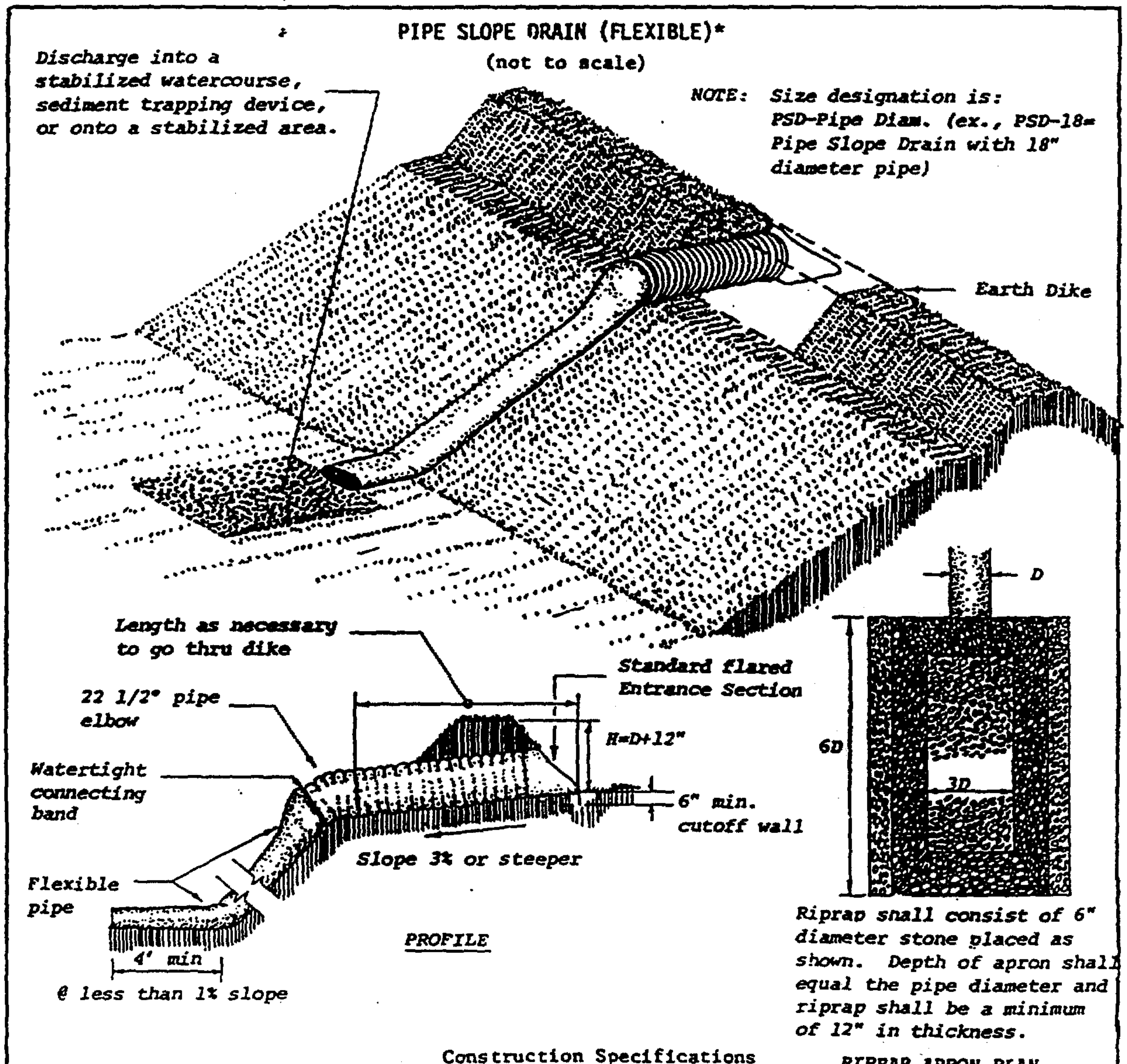


Construction Specifications

SEDIMENT TRAP

Definition

A small temporary basin formed by excavation and/or an embankment to intercept sediment laden runoff and to trap and retain the sediment.

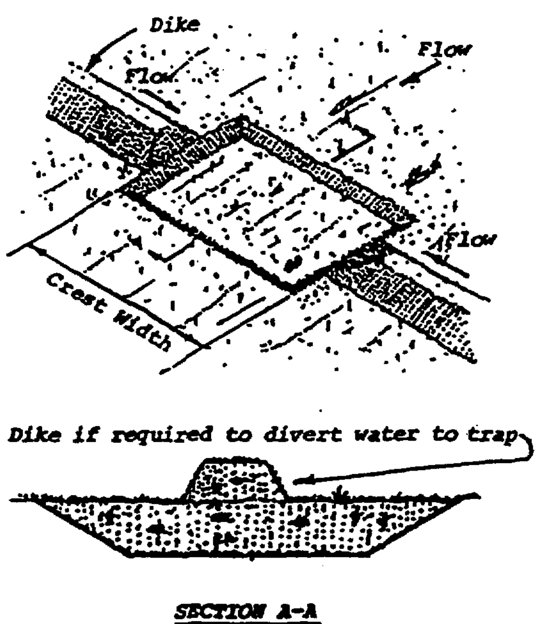
PURPOSE

The purpose of a sediment trap is to intercept sediment laden runoff and trap the sediment in order to protect drainageways, properties, and rights-of-way below the sediment trap from sedimentation.

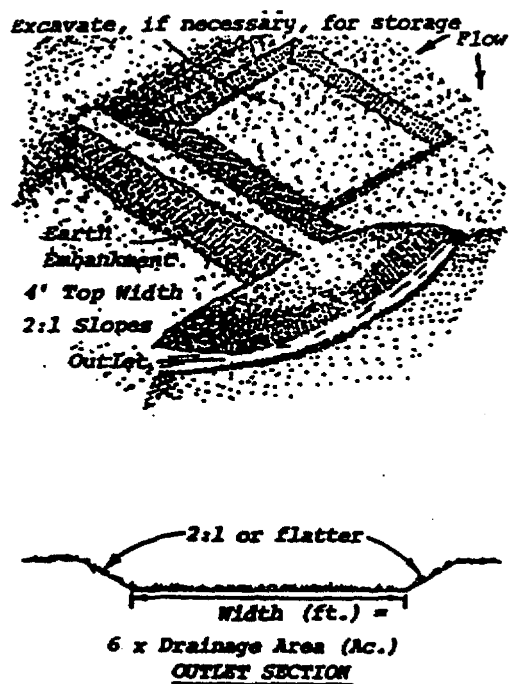
Conditions Where Practice Applies

A sediment trap is usually installed in a drainageway, at a storm drain inlet, or at other points of discharge from a disturbed area.

EARTH OUTLET SEDIMENT TRAP*

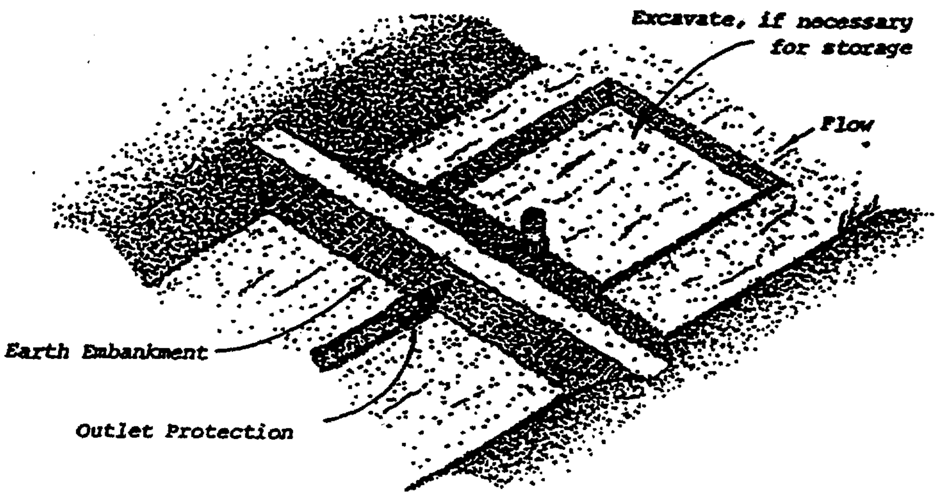


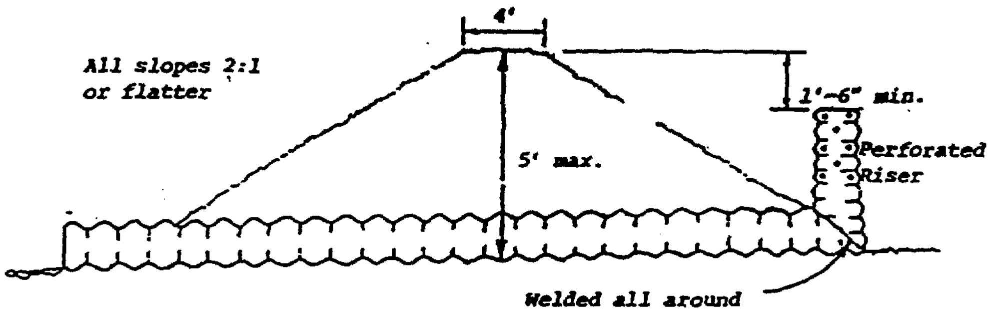
EXCAVATED EARTH OUTLET SEDIMENT TRAP



EMBANKMENT EARTH OUTLET SEDIMENT TRAP

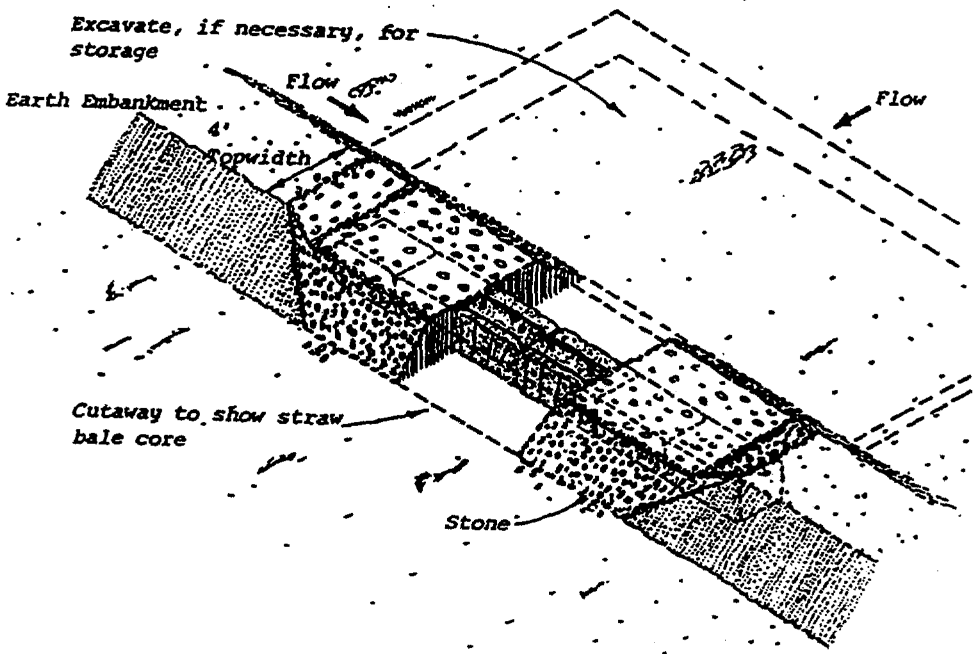
PIPE OUTLET SEDIMENT TRAP*

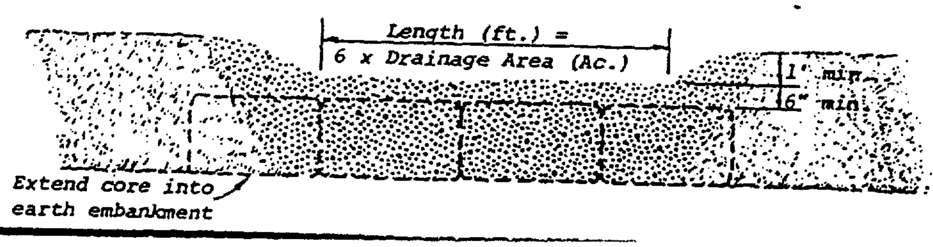




EMBANKMENT SECTION THRU RISER

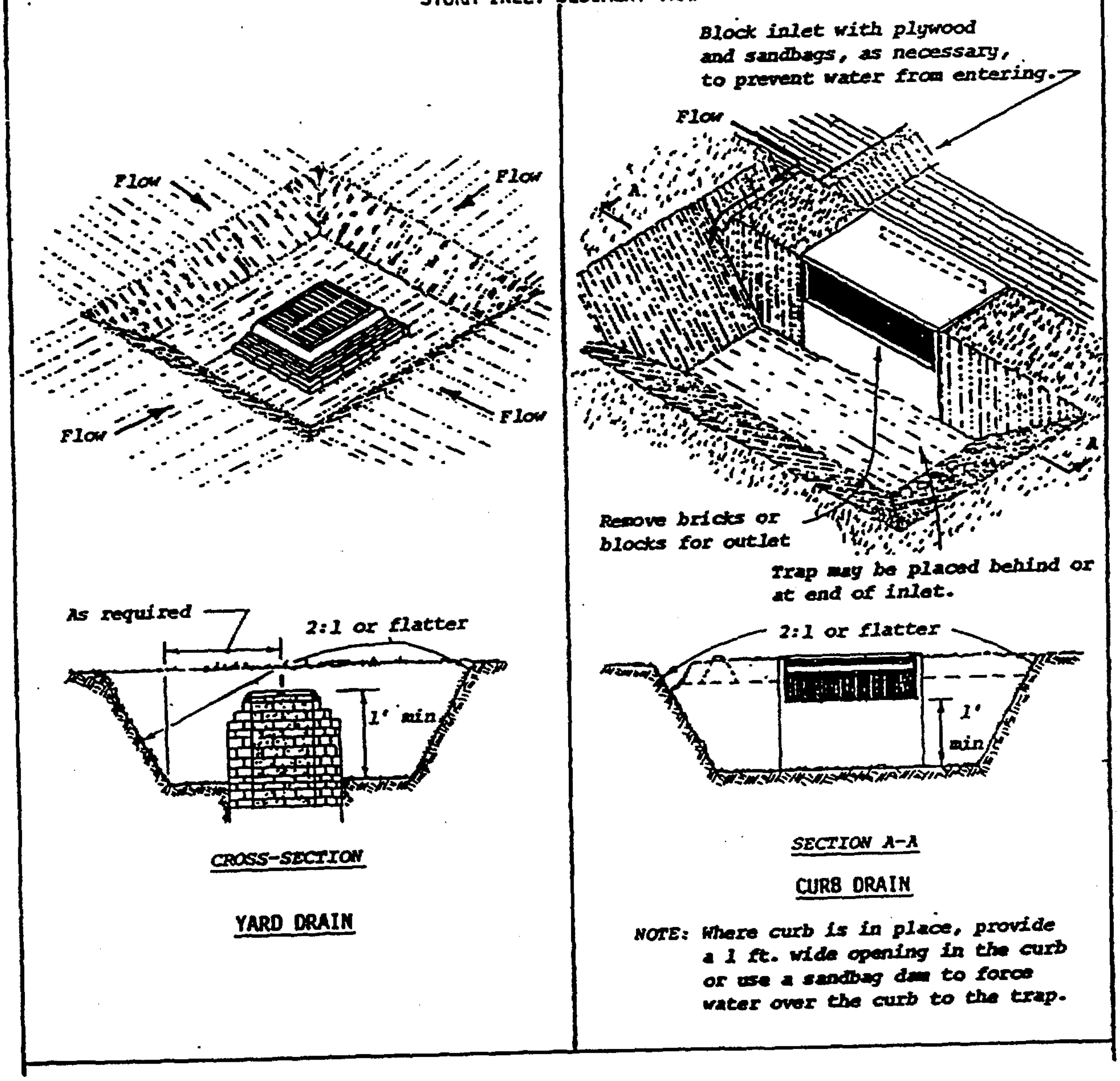
STONE OUTLET SEDIMENT TRAP*





USDA-SCS-Md

STORM INLET SEDIMENT TRAP*



SEDIMENT BASIN

Definition

A temporary barrier or dam constructed across a waterway or at other suitable locations to intercept sediment-laden runoff and to trap and retain the sediment.

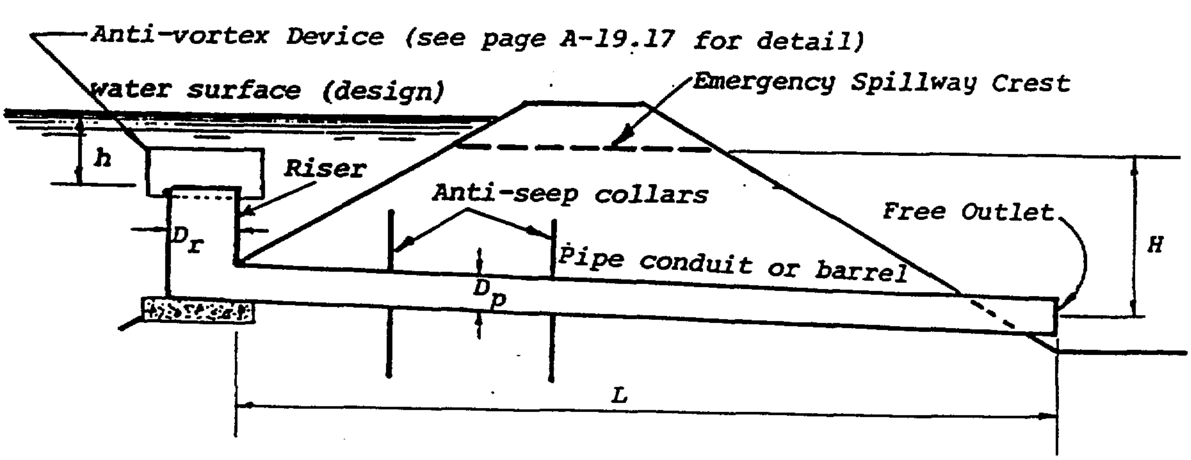
Purpose

The purpose of a Sediment Basin is to intercept sediment-laden runoff and reduce the amount of sediment leaving the disturbed area in order to protect drainage ways, properties, and rights-of-way below the sediment basin from sedimentation.

Conditions Where Practice Applies

A sediment basin applies where physical site conditions or land ownership restrictions preclude the installation of erosion control measures to adequately control runoff, erosion, and sedimentation. It may be used below construction operations which expose critical areas to soil erosion. It remains in effect until the disturbed area is protected against erosion by permanent stabilization.

PIPE SPILLWAY DESIGN



IV
ON-SITE SEWAGE DISPOSAL SYSTEMS (OSDS)

* *Paper not available at time of printing.*

SEPTIC SYSTEM OPERATION AND MAINTENANCE

Julie A. Wright

Cooperative Extension Service, University of the Virgin Islands, St. Thomas, VI 00802

Introduction

A large portion of the habitable land in the Virgin Islands is zoned for residential use. Many of the buildings on this land are not connected to a public sewage treatment system; instead they have individual septic systems. Standard (State-side type) septic systems currently in use in the Virgin Islands have problems properly treating wastewater due to both environmental and demographic constraints. This is because our soils are either too thin (there is not enough soil overlying the bedrock or alluvial aquifers that can filter pollutants) or too impermeable (the soils do not allow wastewater to filter through rapidly enough, causing waste to seep to the soil surface). Similarly, development density contributes to septic system failure by siting systems too close to one another, so close that there is not enough soil per septic system to properly treat the wastewater.

Public Health officials on St. Thomas and St. Croix have reported that over 400 septic systems fail per year on each island. Failing septic systems can contaminate both ground and surface waters with harmful bacteria and viruses as well as nitrate (a nutrient). In areas where septic systems are located in fractured bedrock, bacteria and viruses can be transported very rapidly and contaminate wells, cisterns, and coastal waters. These organisms can cause human health problems--illnesses such as gastrointestinal infections, typhoid fever, and infectious hepatitis have been linked to sewage contamination of drinking waters. Therefore it is very important to make sure cisterns and well casings are properly sealed and separated from the septic system area. Figure 1 presents an example layout of a septic system.

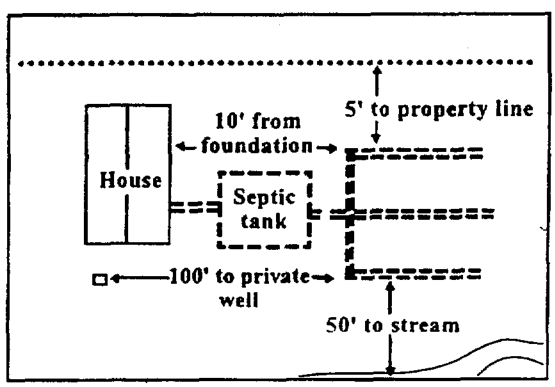


Figure 1. Example of septic system layout.

Other chemicals commonly used by homeowners such as pesticides, paints, varnishes, thinners, and caustic cleaners can also contaminate waters if they seep out of septic systems. Chemical contamination is especially dangerous since some chemicals, even in small amounts, are almost impossible to remove from groundwater.

Failing septic systems can also reduce the value of your property and be expensive to repair. Be aware of the following warning signs that signal septic system failure:

- Sewage surfacing over the drainfield (especially after storms);
- Sewage back-ups in your home;
- Lush, green growth over your seepage pit or drain field;
- Slow-draining toilets or drains; and/or
- Sewage odors.

There are some signs that can tell you if contaminants are reaching surface or ground waters. Look for the following symptoms of sewage contamination:

- Excessive weed or algae growth in the water along shorelines;
- An increase in infections (like staph infections) or illnesses associated with swimming in the area;
- An increase in infections (such as gastroenteritis) or illnesses associated with drinking contaminated water; or
- Unpleasant odors, soggy soil in the area of the septic system, or liquid waste flow over the land surface.

What You Can Do

There are many things that homeowners can do to prevent septic system failure and to ensure that their septic systems work as well as they possibly can. In order to properly care for your septic system, you first need to know where it is located. Unfortunately, manholes and/or inspection ports are often buried in the yard somewhere. To locate your tank, find where, and in what direction, the sewer pipe goes out through the wall in your home and check for manholes just under the surface of the yard in that direction.

Septic system operation and maintenance practices fall under three general categories: septic (or holding) tank monitoring and maintenance; absorption field (seepage pit or drain field) monitoring and maintenance; and system input.

Septic Tanks

Septic systems should be inspected at least once every three years to determine if your septic tank needs to be pumped. (Figure 2 shows a typical septic tank.) While your tank is being inspected, ask the contractor to examine the inlet and outlet baffles (or tees). If either is broken, have repairs done immediately. The inlet should also be checked to see if wastewater is continuously flowing into the tank from previously undetected plumbing leaks.

Your septic tank should be designed to have enough space for solids to accumulate for at least three years. However, how often you need to pump your septic tank depends on:

- The size or capacity of the tank;
- Wastewater flow (which depends on the amount of water used); and
- The volume of solids in the wastewater (for example, a garbage disposal can increase the amount of solids in wastewater by up to 50%).

The contractor hired to inspect your septic tank should use the large manhole when pumping the tank. If the inspection port is used to pump septage the baffles in the septic tank could be damaged. The use of biological or chemical septic additives will not eliminate the need for pumping your septic tank. Some chemical additives can actually harm your septic system by killing the bacteria that break down (digest) the solids in the septic tank.

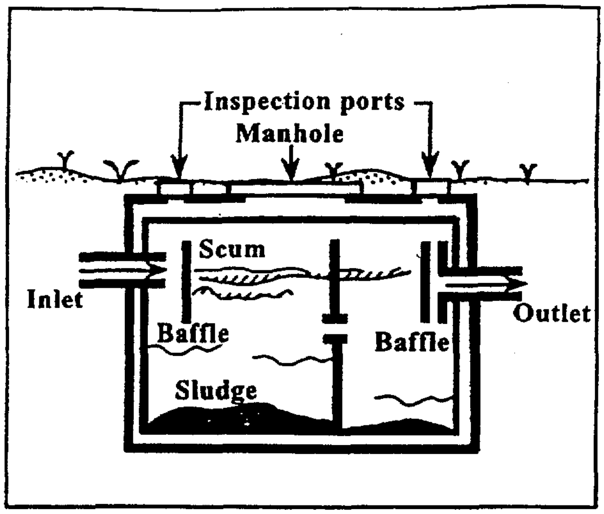


Figure 2. Cross section of a septic (or holding) tank.

It is very important to ensure that there are no cracks or leaks in your septic tank. Septic tank water-tightness is critical to efficient reduction of solids. Leaky tanks allow water to seep in, causing less efficient solids reduction and, therefore, the need for more frequent pumping. Leaking septic tanks also have less storage volume for surface scum (oils, grease and other materials that float on top of the wastewater in the septic tank) and sludge (solids that settle to the bottom of the septic tank). This disrupts the normal solids sedimentation and separation of fats, oils and greases from the wastewater. It also causes loss of bacteria that biologically break down and reduce the volume of solids in the septic tank.

Septic tanks are usually constructed of pre-cast concrete. However, fiberglass and polyethylene tanks are also available. Fiberglass and polyethylene resist erosion and decay and are lighter and easier to transport than pre-cast concrete, but are also more expensive. Whatever material is used for your septic tank, you should make sure taht your tank is properly sealed. A well-designed tank should last at least 50 years.

Absorption Fields

The absorption field of your septic system (the area where the seepage pit or distribution lines are buried) should be routinely checked for sogginess or flooding. These conditions usually indicate:

- Improper drainage;
- A clogged system; and/or
- Excess water use.

The following is a list of some fairly common-sense do's and don'ts that will help your absorption field have a longer life span.

- **Don't** drive over your absorption field with cars, trucks, or other heavy equipment.

- **Don't** plant trees or shrubs in your absorption field--plant only grasses or other shallow-rooted plants (such as banana trees).
- **Don't** cover your absorption field with pavement, concrete or any other impervious surface.
- **Do** divert stormwater runoff away from your absorption field so that it will not flood.

System Input

What you put into your septic system will directly affect the system's health and durability. Many common household chemicals and items can harm your septic system:

- **Do not dump toxic or hazardous chemicals in the toilet or down the drain.** Even small amounts of paints, varnishes, thinners, waste oil, photo chemicals, and pesticides can kill the beneficial bacteria in your septic system that treat wastewater through biological processes. Caustic cleaners and drain openers (like Draino) can also harm your septic system. Instead, use boiling water or vinegar and baking soda to keep your drains unclogged, and use biodegradable cleaners. (A mixture of ½ cup white vinegar, ½ cup ammonia, ¼ cup baking soda, and ½ gallon water is a cheap, effective and non-harmful cleaner.)

- **Do not throw cat litter, plastics, cigarette butts, sanitary napkins, disposable diapers, paper towels, or tissue in the toilet or down the drain.** These products do not readily degrade and can block septic tanks and clog pipes.

- **Do not dump grease, fats or oils down your kitchen drain.** These products will also clog pipes and block your septic system.

Another way to increase the life-span of your septic system is to conserve water. Repair dripping faucets and leaking toilets; avoid long showers; do not run water in sinks and showers while soaping up, shaving or brushing teeth; use water-saving devices like aerators in faucets and showerheads; install water-saving devices (like a brick or weighted plastic bottle) in toilet tanks; and don't flush toilets unnecessarily. The less amount of water that flows through your system, the less work your septic system has to do. These practices will also help you save money on your water bill!

In summary, failing septic systems can cause a serious health threat to your family and neighbors and can degrade both surface and ground waters. However, there are some simple, easy, and low-cost practices that individual home owners can adopt to minimize the risk of septic system failure. Prevention of septic system failure is **ALWAYS** less expensive than replacing a failed septic system!

For more information on the septic systems in the Virgin Islands and ways to prevent water pollution, please contact the your local Extension office (St. Thomas-St. John: 774-0210; St. Croix: 778-0246); the Department of Planning and Natural Resources (St. Thomas: 774-3320; St. Croix: 773-0565); or the Department of Health (St. Thomas-St. John: 774-6880; St. Croix: 773-0565).

ALTERNATIVES TO STANDARD SEPTIC SYSTEMS

Tom H.Linnio

Department of Planning and Natural Resources,
St. Thomas, U. S. Virgin Islands

On site treatment of domestic and commercial wastewaters has been and is today a major topic involving the health and environmental well being of the community The United States Virgin Islands has tremendous contribution to non-point source pollution from the current treatment or lack of adequate treatment of domestic and commercial waste water. Of particular concern for the Virgin Islands is the excessive nutrient loading from phosphates and nitrates of the costal waters resulting in the death of reef systems due to algal growth.

The de facto "standard septic system" in the United States Virgin Islands is a septic tank with a minimal if not totally unacceptable leach pit. Leach fields are very rarely used, to the point of being almost unheard of. The dominant soils of the Virgin Islands are clays or soils with a high clay content, often with moderate to steep slopes. Although the Virgin Island Rules and Regulations has a section on Percolation tests, specifically T.19, Section 1404-91, percolation tests are rarely if ever performed. This lack of performance of percolation tests results in improper evaluation, design, sizing, and placement of on site wastewater treatment. One could say with a fair degree of confidence that the majority of the "standard septic systems" in the Virgin Islands are not functioning properly, if functioning at all, as far as treatment of waste waters are concerned. With the majority of soils in the Territory being thin with very poor adsorption qualities and moderate to steep slopes, no development involving proposed on site wastewater treatment should be permitted without verifiable percolation test, proper design and siting of wastewater treatment structures. The need for percolation tests and proper wastewater treatment design, sizing and placement based on the test can not be over stated.

Another factor that compounds the wide spread improper use of leach pits is the lack of maintenance of the septic tanks. The normal maintenance of a septic tank requires periodic cleaning to remove solids. This is not a standard practice in the Territory. When solids move into the leach pit, the pit becomes clogged and stops functioning as an absorption structure and becomes a cess pool. This results in an increase in down slope nutrient loading, contamination of ground water and a potential major health risk.

This problem is not limited to leach pits alone. Generally all systems with septic tanks and absorption structures must have the tanks maintained and cleaned to avoid movement of solids to the absorption structures. Failure to properly clean out septic tanks will cause clogging and plugging of the absorption structure which are then ruined and must be replaced, often at a great expense.
There are no maintenance free wastewater treatment systems.

Having so far discussed some aspects of the "standard septic systems" current in the Territory, I shall now discuss briefly some alternatives. I must begin by stating the obvious that the best alternative is a well run and maintained system of sewers and treatment plants. But since that is not foreseeable, I will focus on some on site alternatives. A review of existing resource materials available in the territories was to say the least, rather disappointing. Luckily there is the EPA Small Flows Clearinghouse. The Small Flows Clearinghouse was established in 1977 by legislation under the Clean Waters Act as a national information center for (among other related topics) alternative sewage technologies. You can find in the back of this presentation a current listing and order form for Small flows products. Also in the back you will find a short glossary of terms often used in septic wastewater treatment.

Serial Distribution for sloping ground.

This is a modified tile field system, where based on percolation test results a series of absorption fields are laid laterally with slope contours and tied together with a series of distribution drop boxes. This system has the advantage of being able to adjust to site conditions, the leach lines can be of varying lengths. The trench increase absorption areas versus a leach pit. This system can be seen as a demand system since the various absorption trenches come in to play as a function of the load on the system. In the dry season only the upper trenches may be in use, where as in the wet season the whole system might com into play. This allows at least part of the system some resting periods. The system is easily expandable by the addition of drop boxes and trenches. The system is fail-safe. If the septic tank is not properly clean only the first trenches will plug and fail, the whole system will not be ruined. I feel this system has great potential in the Territory, if properly designed to the soil condition on site.

Wisconsin Mound or Transvap Soil Absorption System

This system is a modified tile field system that is placed above existing grade. This system might be of use where soil and or site conditions restrict use of sub-surface absorption systems.

The system relies on selected sand and soil fill to treat septic tank effluent. Basically a tile field is laid in a sand and soil bed above original grade. The amount and depth of bed area required depends on site soil conditions and depth, depth of water table and or bedrock, quality of the fill material, waste water volume (loading), and other site and use related factors. The bed or mound should be long and narrow. This system may have the disadvantage of needed a sump pump, if the septic tank is below the mound or bed elevation. This system may have some positive limited use in the Territory for some very difficult sites.

Sand Filtration

The use of sand filters may be adapted for many types of systems such as surface, subsurface, intermittent, and demand flow. All system must have properly selected sand beds of 24 to 30 inches deep to filter, oxidize and degrade the secondary treated sewage. Surface sand filters generally are a system that irrigate the secondary treated sewage (grey water) over a sand bed. Subsurface filters are generally a tile field over the sand bed, this system may have a separate lower tile field under the upper tile field and sand filter leading to a separate leaching field or even to a sewer. Intermittent sand filter feed the sand bed in controlled doses, by timed pumping, dose buckets, siphons or other methods. Intermittent system can be either surface or subsurface type. Sand filter can be very useful in soils where percolation tests show restrictions. The sizing and siting of the sand filter will be determined by the site soil characteristics, depth to water table, use, and loading among other factors. The proper selection of sand in size and type is critical as in the use of filtration matting to avoid clogging by particles from surrounding soils. The use of sand filter has high potential in the Territory.

Composting Toilets

The composting toilet system is a self contained system which is usually dry with some models using a foam flush. The wastes is collected inside the composting unit, or goes to an outside composting tank. Some units with outdoor composting tanks are designed so as to be solar driven. In either system the composting tank is vented to minimize odor. With the use of selected microbes, the waste is degraded to a humus. This system has been successfully used in the Territory, particularly on St John. One draw back seems to be a problem with cockroaches, therefore I would recommend if the system is to be used that the outside composting tank type with a good seal between outside and inside be used.

Aerobic Digester

Aerobic digester are generally special subsurface secondary treatment tanks into which ambient air is pumped or compressed to supply respiratory oxygen for aerobic bacteria. The function of the aerobic bacteria is to degrade the secondary wastewater. The systems can be as simple as just an air pump and an emitter, or can have rotation biological contact drums, paddles, impellers, which are powered by the air pump or compressor before the air goes to the emitters. Aerobic digester can be very useful in decreasing the biological oxygen demand (BOD) before the wastewater goes to the leach field or pit. This can allow, if properly designed and sized a smaller leach field than might be otherwise required. Aerobic digesters also can be used increase the useful life of a leach field. Many of these digester come as pre-made packages, often made of fiber glass for ease of installation. They do require a power source to run the air pumps or compressors. Some unit use solar panels and batteries to supply the power to the pump or compressor. This type of technology has good potential for use in the Virgin Islands.

Anaerobic Digesters

Anaerobic digesters relay on anaerobic bacteria to degrade the wastewater. Anaerobic bacteria generally must have an environment lacking in "free" of molecular oxygen. This type of digester often is a below ground treatment tank which is packed with a contact medium, often red wood bark. Anaerobic digester can also be above ground, indeed this type of digester is common used in marine service on boat, ships, off shore drilling platforms etc. One advantage for costal or marine use in the anaerobic bacteria are capable of denitrifaction, the is to say they can degrade common nitrogen compounds. Nitrogen compound such as nitrates and nitrites are very harmful sources of nutrient loading, killing reefs by causing algal blooms. Aerobic bacteria are not known for denitrifaction where as anaerobic bacteria are. This system is not uncommon in the Territory though one can not say it is widely used. Some years ago the Government did use this system for facilities near the coast and off the sewer lines. It had good initial success, but failed in the end from lack of proper maintenance. This system has great potential in the Territory for areas with clay soils, coastal area, areas with high water tables, and small lots. This type of system does require some more ongoing maintenance than some other systems.

Subsurface Emitters with Trees

This system uses a modified leaching and irrigation system where emitters packed with red wood bark are place and a tree is planted above. This system works with the evapotranspiration increase that the planted trees supplies. The redwood bark packing from reports not only increases the biological contact area, but also appears to prevent the tree roots from growing into the emitter and clogging the system.

This is a fairly new system with good results so far. This system may be a good alternative to the current practice, particularly of hotels, of using sprinkler for irrigation of gray water.

Wetlands Systems

This is another fairly new technology that has been tested and proven on both large and small scale. This is a secondary treatment where the primarily treated waste water is feed into an artificial wetland system. For residential or small scale commercial uses a two cell wetland with liners is currently used for treatment. The cells have specialized distribution, gravel or gravel and sand bed and use reeds and other wetland plants. Another cell which is not lined can be used for leach or the treated water may go to a leach field, or even be discharged in to a waterway if permitted. This system is solar driven, that is to say the sun supplies the energy to run this system This system works with biological degradation, biological uptake, evapotranspiration and if properly maintained should decrease nitrogen and phosphate compounds. If the system is properly designed, sized and maintained there is no ponding, so mosquitos should not be a problem This system is currently under study by EPA and the Tennessee Valley Authority and has been successfully used in many areas.. I feel this system has great potential for use in the Territory.

Green House Ecosystems

This system can be viewed as a combination of a marsh or wetlands with aquiculture and is another solar drive system which also uses pumped or compressed air. In this system wastewater is first equalized, then clarified and oxygenated. The wastewater is then pumped to a series of solar silos, then to marsh cells from which the water is treated by ultra violet lights and finally discharged. The plants are run in parallel in case of failure due to poisoning from improper chemical that might be place into the waste water. With a parallel system if one leg is knock out the other leg can supply the end microorganism, organism and plants. This system uses biodegradation, biological uptake evapotranspiration and should be able to treat nitrogen and phosphate compound if properly run. This system has been proven on both fairly large and small scales and may have good application in the Territory. It is not though a system for the average single homeowner.

Incineration

Incineration of toilet waste product has some limited application, in this system toilet wastes are incinerated using LP gas, propane or electricity. It is not meant to deal with other bathroom or kitchen waste water. Most often used in summer camps and similar applications, this system invented in the 1930's has never been widely used.

There are some other types systems such as recirculating toilets, electrolysis, water hyacinth basins which are used sometimes. I mention these here in passing. The systems that I have presented I feel have better chances of application in the Territory.

SEPTIC SYSTEM STUDY FOR THE VIRGIN ISLANDS

Non-Point Source Pollution Committee
Virgin Islands Department of Planning and Natural Resources
Virgin Islands Conservation District
Virgin Islands Conservation and Development Project Council

INTERIM REPORT PART 1 (Revised)

INTERIM REPORT PART 2 (Draft)

IV-11

DRAFT ABRIDGED EDITION
For Presentation at the First Annual Virgin Islands Conference on Nonpoint Source Pollution
October 5, 1993

Presented by Barry W. Kimball P.E.
EXCERPTS FROM SEPTEMBER 1993 REPORT

Kimball Chase
Engineering ■ Surveying ■ Land Planning & Design
45 Raphune Hill
Suite 501 #144
St. Thomas, U.S.V.I. 00802

INTRODUCTION

Man's carelessness in the management of his own excreta can result in a number of diseases as pathogens from an infected person find their way by water, food, or soil to another human being. The first line of defense would appear to be simple; manage our waste so that none of it reaches drinking water or food supplies and isolate it from the ground surface where it is accessible to animals, including insects and birds, which can be direct carriers of pathogens.

Since its introduction in the United States in 1880, septic tank systems have become the most widely used method of on-site sewage disposal. Although the concept and design of the septic tank/soil absorption system are relatively simple, the system involves complex physical, chemical, and biological processes. Performance is essentially a function of the design of the system components, construction techniques employed, characteristics of the wastes, rate of hydraulic loading, climate, aerial geology and topography, physical and chemical composition of the soil mantle, and care given to periodic maintenance (USEPA, 1977).

The septic system's recent reputation as a major contributor to environmental pollution is not the result of the system's inadequacies, but rather the result of a misuse of this disposal practice. The septic tank system is a combination of unit processes which were initially intended for rural farm families. Its widespread use in suburban areas has resulted in many installations where the septic system has been squeezed onto small lots, in soils of limited suitability and has been neglected by the home owner. The septic tank/soil absorption system has demonstrated to be ill-fitted under these adverse circumstances.

For residences on the U.S. Virgin Islands, the conventional septic tank/soil absorption system consists of two (2) major components, a water tight compartment (septic tank) and a provision for liquid effluent discharges to the subsoil (leaching trenches or seepage pits). The septic tank serves simultaneously as a separation unit and as a storage and digestion unit for the retained scum and sludge. A leaching structure is used to dispense the liquid septic tank effluent into the soil, and therefore must be constructed in soils capable of accepting and dispersing the liquid.

The original intent of this study was to find ways to improve upon the conventional septic tank/soil absorption system and septic system regulations to bring them into compliance with the usual standards for design and construction for on-site disposal of sewage effluent. The strategy in performing this study was to assume that subsurface soil absorption (disposal trenches, beds, seepage pits) is the preferred on-site disposal option because of its reliability with a minimal amount of maintenance. The process was then to analyze the soils, topography, geology, and other characteristics of the Islands so that the regulations could be customized to fit the specific circumstances. In those areas where the site characteristics are unsuitable for soil absorption systems, alternative methods would be investigated as a last resort for on-site disposal since these alternatives are typically the most costly to construct and require a great deal more maintenance and supervision than soil absorption systems.

Now that the analysis of the Islands characteristics is completed, we have found that the vast majority of the Islands' land areas are unsuitable for soil absorption systems. We have also found that thousands of the septic systems currently in operation have been located in areas that are inappropriate for subsurface disposal and represent not only a hazard to the environment, but more importantly, a risk to the public's health. There is a great lack of understanding among regulators, home owners, developers, and contractors about how septic systems operate. Examples of this misunderstanding is the acceptance of seepage pits constructed directly in fractured bedrock and leaching trenches installed in impervious clays, both of which are located on small lots in densely populated neighborhoods. Very few people on the Islands understand, that for soil absorption septic systems to operate properly, septic tank effluent must be filtered through at least 2 to 4 feet of pervious soils before it can be discharged to the environment. This basic tenet of septic system design is what makes the traditional soil absorption system unsuitable for almost all locations on the Virgin Islands. Most of the land surface does not have 2 to 4 feet of soil or, in areas where there are deep soils, it is typically impervious.

The focus of this report is now to explain and justify the reasons why the conventional subsurface disposal system is inappropriate for almost all developable areas and offer alterative disposal options that may be suitable.

The report's recommendations are expected to stimulate discussion on the different approaches for regulating the installation and use of sewage disposal systems. Readers are encouraged to express their views and opinions in writing to the Department of Planning and Natural Resources. The Department has indicated that it will fully evaluate all comments prior to formulating revisions to the Regulations. Comments may be submitted to the following:

Adrian Schottroff, Chairman NPS
DPNR/DEP

Mario Morales
RC&D Coordinator, SCS

PHYSICAL CHARACTERISTICS OF THE U.S. VIRGIN ISLANDS

TOPOGRAPHY

St. Thomas

St. Thomas has an extremely irregular coastline and is very hilly with practically no flatland. The highest hills are generally found near the center of the Island, with Crown Mountain at 1,550 feet the highest point. The Island is relatively small and many of the peaks rise above 1,000 feet. This results in rather steep slopes over all the island, so that rainfall runoff is quite rapid and there are no permanent streams or rivers.

St. John

Like St. Thomas, St. John has an extremely irregular shoreline and a very hilly topography. It has a number of peaks over 1,000 feet, topped by Bordeaux Mountain at 1,297 feet in the eastern portion of the island. Slopes are quite steep over all of the island, and there are very few areas of flatland. There are no permanent rivers or creeks.

St. Croix

St. Croix is the largest of the three U.S. Virgin Islands. The topography is somewhat different from the other two with a broad expanse of low, relatively flatland running along the southern two-thirds of the Island. The North End Range, a series of hills, ranging in elevation from about 500 feet to more than 1,000 feet, topped by Mount Eagle at 1,165 feet, runs along the northern coast. East End Range of St. Croix is another group of slightly lower hills with a maximum elevation of about 860 feet found on the eastern end of the island. The area covered by hills on St. Croix results in rather steep slopes down to the Caribbean in the north and to the level areas to the south.

GEOLOGY

The U.S. Virgin Islands are located at the eastern end of the Greater Antilles island chain and are comprised of the three major islands of St. Croix, St. Thomas and St. John as well as some 50 smaller islands and cays. St. Croix is the largest of the islands (85 square miles). It lies about 40 miles south-southeast of Puerto Rico and about 40 miles south of St. Thomas (30 square miles). St. Thomas lies approximately 40 miles east of Puerto Rico and 2.5 miles west of St John (19 square miles).

The Eagle Mountain Volcanics of St. Croix has been intruded by a large mass of gabbro in the Fountain Valley region of the North Side Range and by a similar mass or doirite in the East End Range between Great Pond and Southgate Pond During late Cretaceous or Early Tertiary age. Up to this time The Mount Eagle Volcanics was one continuous ridge. Sometime during Early to Middle Tertiary age St Croix's central valley was created by a downthrown block (grabben) as a result of normal faulting and St. Croix consisted of two islands separated by a deep marine basin in which as much as 7,000 feet of clayey sediments known as the Jelousy Formation. Alternating deposits of planktonic material and sediment - gravity flows which accumulated in deep water during Oligocene and Miocene age form the limestones and marls of the Kingshill Formation. The Kingshill Formation (known locally as Caleche) extends across the south and central plains of St. Croix. Along the southwestern coastal plain, thin deposits of shallow water benthic organisms overlap the Kingshill Formation.

Recent geologic processes occurring on the U.S. Virgin Islands consist primarily of surface weathering of the bedrock formations, erosion, and the deposition of alluvium along intermittent stream channels, in coastal embayments, and as alluvial fans along the southeastern base of the North End Range of St. Croix. These processes have configured the landscape of the islands and has formed the parent material base upon which the soils of the U.S. Virgin Islands have developed.

SOILS

Soils of the U.S. Virgin Islands have been characterized by SOIL SURVEY, VIRGIN ISLANDS OF THE UNITED STATES published by the United States Department of Agriculture, Soil Conservation Service in August of 1970. This publication contains descriptions of the soil types identified and mapped by the soil survey, physical data, interpretations of their suitability for various uses, and maps at a scale of 1:15840 depicting their lateral extent. Although this document has been a valuable tool for land use planning, its information is old and has become outdated with respect to the current understanding of the U.S. Virgin Islands soil resources.

The USDA Soil Conservation Service is currently in the process of a re-classification and correlation of the soil resources of all the islands. Some of the soil series recognized by the 1970 publication will continue to be recognized through this process. Many of the old soil series, however, will be discontinued and new series formulated to more accurately describe the characteristics of these resources. Field mapping of St. Croix and St. John has been completed and mapping is in process on St. Thomas at the time of this report. Unfortunately, detailed maps will not be completed or available for use in this study. Indications are that they will be available for use in the near future. In anticipation of the availability of this information, this study will use the information that is currently available for the new Soil Survey. Table 1 lists the names of the soil series proposed for this survey.

Soil Wetness:

Soil wetness conditions or drainage classes refers to the depth within a soil that saturation or near saturation by the ground water table is encountered and is an important design consideration for septic systems in may parts of the country. Due to the hydrogeologic conditions of the U.S. Virgin Islands however, ground water tables rarely approach the ground surface and is not an important tool in land use planning decisions with the exception of a few soil series which will be noted later in this section.

Analysis of the physical characteristics of the Virgin Islands soil resources indicates three major categories of soil groupings which, with a few exceptions, should act similarly with respect to the design and operation of septic systems. These categories are closely related to the parent materials in which the soils have developed and are designated as Volcanic, Calcarious Marine Sediments, and Alluvium. Table 2 presents a soil catena relationship for the proposed soil series in which they have been sorted based on their parent materials and then arranged with respect to their typical landscape position. It should be noted that the Jaucus and Sugar Beach series have been placed in the Alluvium category for the purposes of this discussion. Jaucus consists of beach deposits of calcarious marine sands while Sugar Beach develops on deep organic (muck) deposits. Generalized soil maps showing the distribution of these categories for St. Thomas, St. John and St. Croix are presented as Figures 1, 2, 3, respectively. As the new soil survey maps are not available, these maps have been prepared using geologic maps of the islands showing the spatial relationships of the parent material groups.

Volcanic Soils:

Soils developed from volcanic parent materials are the most wide-spread category on St. Thomas, St. John and in the North End and East End Ranges of St. Croix. For the most part they have formed in thin mantles (less than two feet) of materials weathered from the underlying volcanic bedrock formations and occupy slopes of up to 75% or more with slopes in excess of 35% being very common. The volcanic parent materials weather to form highly structured soils with textures of clay and clay loam, usually with a gravelly or very gravelly component.

Montmorillonite clays (high shrink swell capacities) are minerological components of the Jelousy, Parasol, Sussannaberg and Fredriksdal series. Areas of volcanic parent materials with Montmorillonite clay minerology are noted on the generalized soil maps.

Permeability for the soils in this category is reported to be moderate with the exception of the soils with Montmorillonite clays which have slow permeabilities. Exceptions within this category are the Parasol and Jelousy soils which have developed over the gabbro and diorite intrusions on St. Croix and are deep and very deep, respectively, to the underlying bedrock formations.

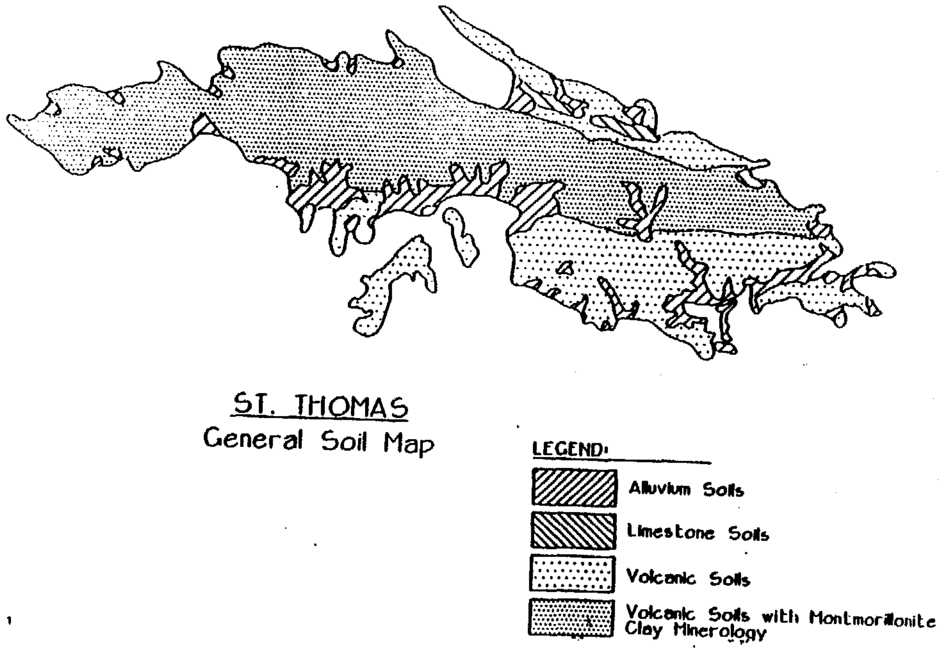
Calcarious Marine Soils:

Soils developed from calcarious marine sediments are Arawak, Sion and Hessleberg. They have developed in parent materials derived from the calcarious marine sediments of the Kingshill Formation found on St. Croix. Arawak is a shallow soil located on the summits and upper side slopes of the limestone hills and are gentle to very steeply sloping (up to 75%). Sion found on the lower side slopes and valley floors of the limestone deposits, is very deep and gentler sloping (0-12%). Hessleberg has developed on shallow marine terraces along the southeastern shore of St. Croix and is distinguishable due to a hard petrocalcic layer present within 20 to 30 inches of the soil surface. These soils are underlain by a soft limestone marl which is known locally as Caleche. Permeability of these soils is moderate. Textures are clayey.

Alluvium:

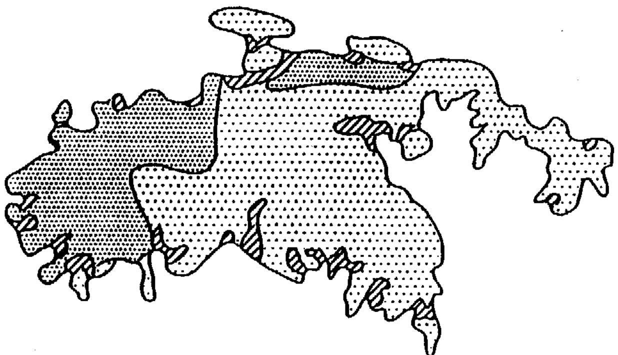
Soils which have formed in recent alluvial deposits on the islands can be separated into two groups, those having development potential and those that do not. The latter group is comprised of soils associated with natural resources that have significant value to the benefit of the general public and should be preserved. These ares include mangrove swamps, salt marshes, salt ponds, tidal flats, beaches, and areas with high water tables adjacent to these resources and in gut floodplains. Soil series typically found in these areas include Sugar Beach, Sandy Point, Jaucus, Solitude, Cornhill, and Carib respectively. Any of the other series in the alluvium category may also be included in this group when they are located within or directly adjacent to drainageways, locally known as "guts".

The remaining soils in this category have developed in sediments on alluvial fans, terraces, plains and lower side slopes. Cinnamon and Glynn are formed in fine textured sediments from extrusive volcanic rocks which overly stratified fine to coarse textured sediments. Hogensborg is formed in clayey sediments with Montmorillonite mineralogy derived from intrusive volcanic rocks, specifically the gabbro and dorite intrusions found in the North End and East End Ranges respectively on St. Croix.



ST. THOMAS
General Soil Map

Figure 1



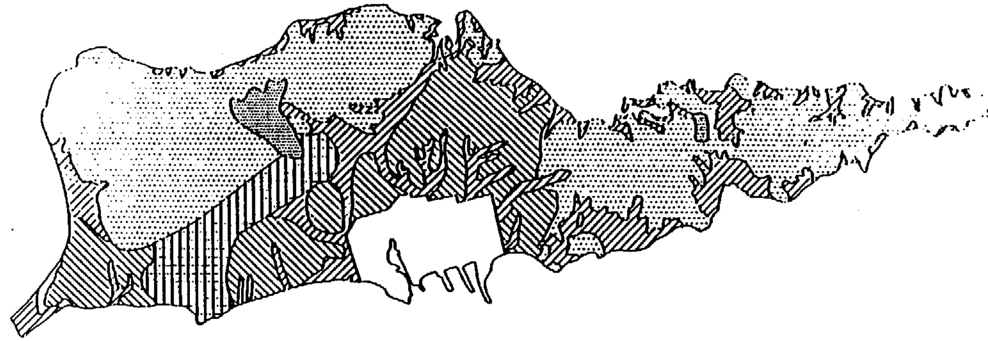
ST. JOHN

General Soil Map

LEGEND:

- Alluvium Soils
- Volcanic Soils
- Volcanic Soils with Montmorillonite Clay Minerology

Figure 2



ST. CROIX

General Soil Map

LEGEND:

- Alluvium Soils
- Limestone Soils
- Alluvium Soils with Montmorillonite Clay Minerology
- Volcanic Soils
- Volcanic Soils with Montmorillonite Clay Minerology

Figure 3

GROUNDWATER:

Groundwater in the U.S. Virgin Islands is a limited resource which has been estimated by the U.S. Geological Society to supply approximately 20% of the total water needs of the islands population and industry (Torres-Sierra and Rodriguez-Alonso 1986). The development and operation of groundwater production wells has been recognized as the most cost effective source of drinking water available on the islands (C2HM Hill, 1983) and as water demand increases it is likely that pressured to develop groundwater sources to their fullest capacity will also increase. Investigation into the extent, quantity and quality of groundwater aquifers has received considerable attention by the U.S. Geological Survey, the Water Resources Research Institute of the University of the Virgin Islands and several private consulting firms in conjunction with governmental agencies.

Concerns for public health have prompted the U.S. Environmental Protection Agency to establish primary and secondary water quality standards for drinking water supplies. Contaminants of primary concern that are introduced into the environment from the application of waste-water are pathogenic organisms (bacteria, viruses, and parasites), nitrate nitrogen, and synthetic organic compounds. Pathogenic or disease causing organisms are introduced through the feces of individuals who are either infected with the disease or are carriers. Nitrates are formed from the mineralization and nitrification of organic compounds found in waste-water by aerobic microbes. Synthetic organic compounds are contained in cleaning agents and other man-made products which are being commonly used in the house-hold. A more thorough discussion of these contaminants, their modification and disposition through septic system operation is contained elsewhere in this report.

The proper design and construction of septic systems is effective in the removal of pathogens through soil treatment of waste-water prior to its discharge to the underlying water table. The presence of fecal bacteria within a groundwater aquifer is a prime indicator that direct connection/s between the aquifer and inadequately operating septic system/s can exist. A saturated flow zone between the disposal mechanism (trench, seepage, etc.) and the water table or fractured bedrock formations are the most common avenues cited in the literature for the migration of pathogens over long distances. The maximum contaminant level established for bacterial in drinking water is one colony per 100 milligrams of water.

Nitrates, on the other hand, are generated from the application of waste-water through conventional septic system operation, regardless of design and construction considerations, and surface discharge of improperly treated waste-water. Nitrate levels within an aquifer is determined by the density of development which discharges its waste-water within the catchment area supplying recharge to the aquifer and the amount and quality of water recharging the aquifer. Nitrate nitrogen levels within a aquifer, therefore, is a useful tool in assessing development impacts to groundwater quality and the level of development controls necessary to maintain groundwater quality level within acceptable standards. The maximum contaminant level for nitrate nitrogen in drinking water has been established at 10 milligrams per liter (mg/l). Nitrate nitrogen levels above 1 to 2 mg/l are typically considered to be elevated above natural background levels.

Investigation into the groundwater quality of the U.S. Virgin Islands has been conducted by Geraghty & Miller (April, 1983), the U.S. Geological Survey (Garcia and Canoy, 1984 and) and others. Geraghty & Miller collected and analyzed inorganic chemical quality data from several sources within the Fairplains and Barron Spot well fields as well as from 78 private wells on St. Croix. Inorganic chemical quality was also gathered from several wells in the Turpentine Run basin on St. Thomas. They reported nitrate nitrogen levels of 3.5 to 4.6 mg/l in the Fairplains wells, 3.8 to 7.4 mg/l in the Barron Spot wells, and several other areas on St. Croix with levels which approach and in some cases exceed the 10 mg/l maximum contaminant level establish by EPA. Four wells in the Turpentine Run Basin on St. Thomas were reported to have nitrate nitrogen levels in excess of 10 mg/l with four of the other wells sampled having levels between 3 and 5 mg/l.

Garcia and Canoy collected and analyzed water samples from 8 wells on St. Croix, 7 wells on St. Thomas, and 4 wells on St. John for inorganic chemical quality as well as fecal coliform and fecal streptococci bacteria. Nitrate nitrogen exceeded 1.0 mg/l in ten of the wells sampled with two of the wells being in excess of 5 mg/l, and all of the samples being below 10 mg/l. Fecal bacterial were detected in all but one of the wells with fecal streptococci being detected as high as 5,800 colonies per 100 milliliters of sample.

In 1986 Knudsen conducted a study to evaluate the presence of water borne pathogens in the various drinking water sources of the U.S. Virgin Islands and the ability of standard testing requirements to detect them. Samples were collected from cisterns, wells and points along the public water system. Human pathogenic bacteria were found to be present in all of the 16 sampling points with fecal streptococcus being present in all but one sampling point.

In 1986 the U.S. Geological Society compiled chemical water quality analyses of water samples collected between 1965 and 1985 from the principle aquifers of the U.S. Virgin Islands (Zack, Rodriguez-Alonso and Roman-Mas, 1986). A total of 169 samples were analyzed for nitrate nitrogen; 21 from the Kingshill aquifer on St. Croix, 140 from volcanic bedrock aquifers, and 8 from coastal embayment aquifers. 75% of the samples collected from the Kingshill aquifer are reported to have nitrate nitrogen levels in excess of 2 mg/l with 50% being in excess of 8 mg/l and approximately 40% exceeding 10 mg/l. Of the volcanic bedrock samples, 50% exceed 2 mg/l and approximately 30% exceed 10 mg/l. Coastal embayment aquifers exhibited better water quality with respect to nitrate nitrogen with less than 20% of the samples exceeding 1 mg/l.

Most authors reviewed have cited septic system practices in the U.S. Virgin Islands as contamination sources and a threat to the quality of the islands groundwater resources.

EVAPORATION

The Bethlehem Upper New Works, St. Croix, gaging station is the only location found on the Virgin Islands that measures evaporation with any consistency. Data from this station shows that average monthly evaporation varies from 4 1/2" per month in the winter to almost 8" in the summer months. The yearly evaporation average is close to 80 inches per year. Normal rainfall usually equals or exceeds evaporation in the months of October and November.

TOTAL EVAPORATION AMOUNTS (inches)
BETHLEHEM UPPER NEW WORKS, ST. CROIX, U.S.V.I.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC
1985	5.39	6.35	6.76	8.38	8.20	8.37	9.59	—	7.23	—	—	4.57
1986	5.57	6.38	—	7.13	—	8.39	7.98	7.73	7.03	5.77	4.45	—
1987	6.08	4.74	7.60	6.61	6.49	—	6.84	6.63	8.21	6.50	5.28	—
1988	5.16	5.70	7.72	7.15	—	5.10	7.21	—	—	—	—	4.44
1989	5.34	—	6.22	—	8.08	—	6.79	7.51	—	—	—	—
1990	—	—	6.62	6.98	7.75	—	—	—	—	—	5.82	—
1991	5.43	5.28	—	8.37	7.35	—	9.09	7.84	8.57	—	7.02	—
MONTHLY AVGS	5.50	5.69	6.98	7.44	7.57	7.29	7.91	7.43	7.76	6.14	5.64	4.51

— Indicates months where information is not available.

From Climatological Data Annual Summary, Puerto Rico and Virgin Islands, years 1985 to 1991, by National Oceanic and Atmospheric Administration

RAINFALL

Annual rainfall values differ from location to location with higher elevations generally receiving greater amounts. On St. Thomas and St. John, annual averages of between 40 and 60 inches. On St. Croix, there is a more noticeable variation from place to place. This island has the greatest annual rainfall, in excess of 50 inches in the northwestern corner. A narrow finger of between 25 and 35 inches extends northeast to southwest over the flatlands south of the hills in the western portion of the island. Records available for the three islands indicate a relatively wet-relatively dry season distribution, but it is not sharply defined. The relatively dry period extends from about December through June. Occasionally, quite heavy rainfall occurs during the so-called drier months. The driest month on St. Thomas and St. John usually is February or March and the wettest month September or October. On St. Croix, the month with the heaviest rainfall, on the average, ranges from September through November.

VIRGIN ISLANDS
PRECIPITATION NORMALS (INCHES)

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
ALEX HAMILTON FLD FAA	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANNALY	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANNAS HOPE	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BETH UPPER NEW WORKS	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CATHERINEBURG	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CHRISTIANSTED FORT	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CRUZ BAY	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DOROTHEA AES	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EAST HILL	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ESTATE FORT MYLNER	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FOUNTAIN	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FREDERIKSTED 1 SE	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GRANARD	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HAM BLUFF LT HOUSE STN	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LAMESHUR BAY	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TRUMAN FLD FAA AP	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WATER ISLE	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WINTBERG	NORMAL MEDIAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

V.I. precipitation normals from "Climatological Data" as published by U.S. Department of Commerce, National Oceanographic and Atmospheric Administration

GROUNDWATER RECHARGE

The rate of ground water recharge in the U.S. Virgin Islands is an important consideration in the management of appropriate septic system densities. Rainfall infiltration which is able to reach the water table is the primary source of replenishment of the various groundwater aquifers, followed by septic systems operation and surface discharges from sewer treatment plants.

The U.S. Geological Society has prepared a water budget for the Islands which indicates that 94% of the rainfall is lost to evaporation and transpiration by plants. 3% is lost to surface water runoff with the remaining 3% being discharged to the groundwater table. This amounts to a little more than one inch of rainfall per year being introduced into the water table.

ON-SITE SEPTIC DISPOSAL SYSTEMS

GENERAL

Septic systems have long been believed to be an efficient and cost-effective means of disposing of domestic wastewater and have been relied on heavily to support residential growth in urban and rural areas not served by municipal wastewater collection and treatment systems. Until recently there has been relatively little understanding of the contaminants present in domestic wastewater and the soil treatment mechanisms that modify its quality before reaching our ground water and surface water resources. Septic systems were often thought of as temporary solutions to wastewater disposal that would operate only until municipal services were made available. As a result many areas in the continental U.S. which saw high growth rates and dense development in the 40s, 50s, and 60s have experienced a serious degradation of the quality of their drinking water supplies from septic system operation practices.

Within the past 15 to 20 years a tremendous volume of research has investigated these issues. Although by no means complete, the literature is supportive of the pretext that septic systems are a viable alternative in areas where public sewers and wastewater treatment systems are not available or economically feasible. They will operate effectively if they are properly designed, situated in areas suitable for operation, used only for the purposes for which they were designed, and given periodic maintenance.

This section presents the current understanding of the treatment mechanisms that occur as septic tank effluent passes through a soil medium and the resultant effects on ground water and surface water quality.

WASTEWATER CHARACTERISTICS

The design criteria for septic systems, effectiveness of the soil treatment mechanisms, and the resultant pollutant load placed on water resources is in part a function of the characteristics of the wastewater being applied. Wastewater characteristics should be evaluated in two categories: quantity of the wastewater generated and its quality. Both components can vary greatly and are dependent upon the type of use.

Quantity of wastewater has been characterized for a wide variety of uses and can be found in most manuals or codes which characterize septic system design parameters. It is important to recognize that the design flow figures presented in many of these sources incorporate peaking factors to insure that a septic system can accommodate short periods of higher than average water use. While it is important to size the septic system components to accommodate the occurrence of peak water usage, average daily flow figures represent long term trends in water use and are more appropriate for use in evaluating impacts from septic system operation. Literature references indicate that the average daily flow for residential wastewater is in the range of 45 to 60 gallons per capita per day (gpcd).

Synthetic Organic Compounds: Synthetic organic compounds are being detected in domestic wastewater more frequently than ever before. They are contained in cleaning agents, gasoline, and other man-made products which are people flush down toilets and drains. Many synthetic organic compounds are believed to be carcinogenic, and only require very low concentrations to present a public health concern. Many authors believe that the introduction of these compounds to our environment through the use of septic systems may be the greatest threat to our ground water resources in the future.

Other chemical and physical contaminants: In addition to the wastewater constituents noted above, chlorides, metals, and specific conductance (an indicator of salts) are groundwater/surface water quality parameters which are impacted by septic systems and other development related uses.

SEPTIC TANK

Wastewaters are modified through pretreatment processes which occur in a septic tank prior to being disposed of in the soil. These processes include physical separation followed by anaerobic digestion of the waste matter.

Septic tanks are buried, watertight structures designed and constructed to receive the wastewater and to provide a desired detention time before passing it on to the soil for disposal. During this detention period the "floatables" in the wastewater (oils, greases, and some fecal constituents) float to the top, where they undergo some microbial decomposition and form a floating layer of scum. Settleable solids and partially decomposed sludge accumulate at the bottom of the tank where they are subjected to microbial decomposition. The somewhat clarified liquid remaining between the layers of scum and sludge, "septic tank effluent", is displaced from the tank as new wastewater is introduced.

The high rate of microbial decomposition or digestion that occurs in the septic tank quickly utilizes any oxygen present in the raw wastewater and the digestion process operates in an anaerobic or oxygen free environment. Under these conditions, the organic components of the wastewater are partially broken down by microbial enzymes, resulting in a chemical transformation of the nitrogen and phosphorus compounds. The end result being the formation of ammonia (NH_3) and orthophosphate (PO_4) along with methane gas, hydrogen sulfide gas and water. At normal pH levels found within septic tank effluent, the ammonia transforms to the soluble ammonium ion (NH_4+).

Removal of pathogenic organisms in the septic tank processes is a function of detention time and organism reaction to the oxygen deficient conditions within the tank. Organisms have a tendency to become associated with solids and can become incorporated in the sludge. This, coupled with the presence of an anaerobic environment not suited to the survival of pathogens, has led to reports in the literature of significant removal rates within the septic tank. Although removal rates in excess of 99% have been reported for some organisms, the high levels of concentration of pathogens present in the wastes of infected individuals would still result in extremely high numbers of organisms discharged in septic tank effluent. It must be assumed therefore, that the septic tank is unlikely to remove any organism completely, and that septic tank effluent must be considered capable of transmitting any disease whose pathogenic agent is present in the raw wastewater.

SOIL TREATMENT OF EFFLUENT

After pretreatment, the septic tank effluent is conveyed to a disposal area where it is applied to the soil. The disposal area can be of several different configurations, i.e., leachbeds, trenches, seepage pits, etc. The soil treatment processes for each disposal option is the same, differing only slightly on the method of application used to distribute the effluent over the surface of the disposal area. The infiltrative surface between the disposal area and the surrounding soil acts as a filter removing the particulate matter and most of the larger microorganisms (bacteria and parasites).

As the effluent moves through the receiving soil further treatment is provided through filtration, adsorption, and microbial utilization. These processes provide the optimum treatment potential of a soil when the effluent is allowed to pass through the soil under unsaturated flow conditions and oxygen is present for bio-utilization. At appropriate loading rates the remaining bacteria and viruses are effectively removed, the soils phosphorus retention capacity is maximized, and the ammonium ions are converted to NO_3-N. Very little treatment occurs when the effluent is transmitted through the soil under saturated flow conditions resulting in a high potential for bacterial, viral, and other contaminant transport into our ground water and surface water resources.

Distribution:

In gravity distribution systems commonly used in the U.S. Virgin Islands effluent is usually delivered to the disposal area by gravity from the septic tank . The effluent is distributed over the disposal area by gravity flow through 4" diameter pipes containing large perforations in trenches filled with crushed stone or through seepage pits surrounded by stone. If sufficient receiving soil exists, the organic components of the effluent are filtered out and an organic rich biological mat or crust is developed which reduces the infiltrative capacity of the soil and creates a zone of unsaturated flow as the mat creeps across the infiltrative surface. Once full mat development has occurred the reduced application rate promoted by the restrictiveness of the organic mat induces unsaturated flow conditions in the surrounding soil and the quality of the soil treatment process increases greatly. In mature systems the effluent typically becomes ponded above the mat and the anaerobic environment developed in the septic tank is maintained in the disposal area.

Bacteria:

Filtration is the prime mechanism affecting the removal of bacteria from the effluent as it moves through the soil, with the degree of removal being inversely proportional to the size of the soil particles in the unstructured matrix. The infiltrative surface of the disposal area is very effective in this regard, especially in mature gravity flow systems with organic mats that reduce the pore size available for transmission. Filtration continues to occur within the soil and is assisted by adsorption in the removal of bacteria. Adsorption occurs when an organism becomes attached to the surface of a soil particle by chemical bonding between the surface and the organism. Adsorption takes place on the cation exchange sites present within the soil and the rate of adsorption is therefore controlled by soil texture and chemistry. Finer textured soils generally have a greater adsorption capacity than coarser textured soils.

Survival of bacteria within the soil is also an important consideration in the treatment of septic tank effluent. In order to remove the threat of pathogenic contamination of ground water the microorganisms must be rendered inactive. Soil temperature, pH, moisture state as well as antagonistic organisms, soil antibiotics, and the lack of nutrients combine to present a hostile environment for pathogen survival.

Moisture state is the single most important factor controlling the removal of bacteria from septic tank effluent within the soil. The processes described above are most efficient when they take place in aerobic unsaturated soil. Under these conditions the larger pore spaces within the soil are filled with air and the increased moisture tension holds moisture to the surface of individual soil particles and within the smaller pore spaces. Septic tank effluent applied to the soil must flow through the smaller pores and over the soil particles, providing a high ratio of surface area contact to the volume of effluent applied. This promotes filtration and exposes the effluent to more cation exchange sites for adsorption to occur. Higher moisture tensions slow the rate of effluent movement through the soil, resulting in longer residence times for the hostile environment to work on the bacteria. Laboratory and field studies have demonstrated that flow through 2 to 4 feet of aerobic unsaturated soil provides near complete bacterial pathogen removal.

Under saturated soil conditions all or nearly all of the pore space is occupied by water and soil moisture tensions are much lower. Water or effluent applied to a saturated soil moves rapidly through the larger pores, reducing the ability of all of the treatment processes described to occur. The application of wastewater in areas with little or no soil treatment zones over fractured bedrock can also obviate the occurrence of these treatment processes. In nearly all of the studies reporting pathogen contamination from wastewater application to the soil, the point of application was directly into saturated soil conditions and/or fractured bedrock where no zone of unsaturated soil had been provided for treatment.

Viruses:

Because viruses are very small microorganisms, adsorption rather than filtration is the primary soil treatment mechanism effecting their removal from septic tank effluent. Viruses are electrically charged colloidal particles whose charge is negative at most soil pH values. They are adsorbed by anionic attraction at pH's below and by cationic resins at pH's above their isoelectric (neutrally charged) points. Negatively charged viruses are attracted to cations which in turn occupy cation exchange sites available on the soil particles. Virus adsorption capacity, therefore, increases as clay content, cation exchange capacity, and specific surface area increases. Changes in the chemical composition of the soil-water solution, such as ionic concentration, pH, and organic matter can affect a soils adsorption capability.

As with bacteria, the survival of viruses within the soil is an important consideration in effluent treatment. Again, the soil presents a hostile environment which works to render viruses ineffective. Studies indicate that temperature has the greatest effect on survival of viruses with inactivation rates increasing as temperature increases.

For adsorption to be effective, close contact between soil and virus particles is essential. Waste disposal in soil must be done in a manner so that this contact can occur (6). Soil moisture values and effluent flow velocity or loading rate are the two most important factors in insuring that adsorption takes place. High moisture tensions associated with unsaturated soils hold the effluent in close contact with the soil particles while low loading rates provides longer residency times for adsorption to occur. Studies have indicated that unsaturated flow through 1.5 to 2 ft. of sandy fill at loading rates of 5 cm/day will yield effluent which present no health hazard from human enteric viruses.

NO_3-N:

The primary treatment processes operating on nitrogen compounds within the soil are mineralization, nitrification, and denitrification. Nitrogen entering the soil from septic tank effluent is primarily in the form of the ammonium ion and secondarily in the form of organic compounds. Organic compounds are mineralized by microbes within the soil, resulting in the conversion of organic N to the ammonium ion. Ammonium ions are positively charged and are quickly attached to cation exchange sites within the soil. In unsaturated aerobic soil conditions nitrifying bacteria oxidize the ammonium ion to nitrite and then to the nitrate ion (NO_3-). NO_3-N is a highly soluble negatively charged compound which is repelled from the cation exchange sites within the soil and is free to move with the percolating water to the water table. Several studies have indicated that there is a nearly complete conversion of the organic nitrogen and ammonium ion to NO_3-N within the first few inches of entering the aerobic treatment zone.

Once created, some of the NO_3-N can be removed from the percolating effluent, provided soil conditions are present which are conducive to the denitrification of the NO_3-N. Denitrification is a process in which NO_3-N is reduced to gaseous nitrogen compounds by biochemical reduction. Two enzymes produced by facultative denitrifying bacteria under anaerobic conditions (i.e. dissimulatory nitrate reductase and dissimulatory nitrite reductase) are the catalysts which permit this process to occur. In order for denitrification to be a benefit in the treatment process, the percolating effluent must encounter an anaerobic (saturated) soil condition which has a suitable carbon energy source for the denitrifying bacteria. These conditions are most likely to occur in soils that are saturated near the soil surface. One study, in fact, reported very high rates of NO_3-N removal from ground water after flowing only a few feet through wetland soils (poorly drained).

GROUNDWATER IMPACTS

Groundwater is the first recipient of sewage effluent disposed of in properly constructed and designed septic systems. Although the septic tank/soil treatment system is effective in substantially reducing many of the contaminants associated with sewage effluent, the effluent alters the natural background ground water quality in the vicinity of the septic tank leachfield system.

Drinking Water Considerations:

Throughout history, poor drinking water quality has led to numerous disease outbreaks. As a result, the medical profession has promulgated standards for drinking water quality, which offer protection from waterborne disease. The current drinking water limiting standards for the "problem constituents" described above are as follows:

The drinking water standards and maximum contaminant limits are divided into two separate categories. Primary and secondary standards have been established because some of the contaminants listed have been linked to health problems. NO_3-N, synthetic organic compounds and many metals fall into this category.

The secondary standards have been established for reasons of aesthetics, taste, or other non-health reasons. Iron and manganese cause taste and laundry staining problems for instance.

a. Bacteria - One colony per 100 milligrams water

b. Synthetic Organic Compounds - Although standards for common organic compounds vary, many of the current recommended limits are below 100 parts per billion in drinking water, with some recommended limits as low as 5 parts per billion. This is equivalent to one ounce in about 1.5 million gallons. The current drinking water standard for benzene, a common constituent of gasoline, is 5 parts per billion.

c. Nutrients - The current drinking water standard for NO_3-N is 10 mg per liter. There is no drinking water standard for phosphorus.

d. Other Constituents - Drinking water standards for the other constituents are: Chlorides - 250 mg per liter; Specific Conductance - no limit; Toxic metals - varies, but typically lower than .1 mg per liter

SURFACE WATER IMPACTS

Surface water resources of The U.S. Virgin Islands are comprised of two major categories, inland or fresh water resources and coastal water resources. Both categories have been recognized nationally as being vital resources beneficial to the economic and environmental well being of the country. Past human activities associated with cultural encroachment on these resources resulted in wide spread degradation of their quality through the discharges of pollutants and loss through conversion for urban uses. In response to these activities Congress enacted the Clean Water Act (CWA) to abate and control sources of water pollution. The initial thrust of the CWA provided for the regulation of point sources of pollution through the National Pollutant Discharge Elimination System of section 402 of the act and the discharge of dredged and fill material through section 404. In 1987 Congress amended the "Declaration of Goals and Policy" section of the CWA to include nonpoint sources of pollution and enacted section 319 to the CWA, establishing a national program to control nonpoint sources of pollution through the adoption and implementation of management programs. Additionally, in 1990 Congress enacted legislation (Coastal Zone Act Reauthorization Amendments of 1990) which requires Coastal Zone Management programs established under the Coastal Zone Management Act of 1972 as well as Nonpoint Source programs established under section 319 of the CWA to address the impact of nonpoint sources of pollution to coastal waters.

Discharge of domestic wastewater to the environment through the use of septic systems has been widely recognized as a source of nonpoint pollution which can affect surface water quality. Pollutants of concern which have been shown to detrimentally impact water quality are nutrients and pathogens. Nutrients are nitrogen and phosphorous compounds while pathogens are disease causing micro-organisms that are present in the feces of infected individuals. The presence, fate and contaminate transport mechanisms of these pollutants within the subsurface environment is thoroughly discussed elsewhere in this document. Nutrients introduced into the subsurface environment from septic systems are typically delivered to surface water resources through groundwater discharge with the density of septic systems adjacent to these resources controlling the level of nutrients being delivered. Some nutrients and pathogens, resulting from the surface discharge of failed septic systems built in unsuitable soil conditions, can reach surface water resources through urban runoff. Pathogens can also be delivered through groundwater discharge in areas where adjacent septic systems are built to close to or in highly fractured bedrock formations that do not have the ability to remove them prior to the waste stream reaching the groundwater table.

All plant growth requires nutrients as energy sources for metabolism. In surface water environments low levels of nutrients from naturally occurring sources, typically less than 0.3 mg/l for nitrogen and 0.05 mg/l for phosphorous, are the limiting factors controlling aquatic plant growth. The presence of nutrients in concentrations above natural background levels as a result of adjacent human encroachments have been shown to induce excessive aquatic plant growth activity, resulting in a degradation of surface water quality through a process termed as "cultural eutrophication". The increased level of organic matter added to surface water systems through this process can rapidly deplete the resources oxygen supply and block sunlight penetration through increased turbidity levels. These events result in adverse impacts to habitat quality for fisheries and other aquatic plants as well as interfering with recreational activities such as swimming and boating. Phosphorous is typically the limiting nutrient of concern controlling aquatic plant growth in fresh water resources while nitrogen is the limiting nutrient of concern for coastal water resources.

The presence of pathogens in surface water resources is of a concern with respect to health related issues. Recreational activities such as swimming can be impacted from the closing of beaches due to pathogen contamination. Literature review conducted by others report 58 incidences of shellfish waters being closed or restricted in the Mid-Atlantic ocean as a result of contamination from urban runoff and 11 incidences of closure resulting from pathogen contamination from septic systems.

OTHER ALTERNATIVES FOR SEWAGE DISPOSAL

In areas in which an adequate area of suitable soils is not present, or where limiting conditions occur, alternative disposal systems, including surface discharge, evapotranspiration beds and sewage lagoons, are, at times, appropriate.

FILTRATION

Although the use of filtration followed by disinfection and surface discharge is not a recommended alternative for single family homeowner operated on-site wastewater systems, it may present an alternative for small community and hotel developments which propose a single wastewater treatment system to be maintained and controlled by a competent operator.

Single pass surface sand filters are relatively simple mechanical filtration systems which use approximately 24 inches of sand to provide polishing to septic tank effluent intermittently loaded to 2 or more filtration units. These systems may present some odor problems and require periodic raking of the surface to break-up the hard crust which develops. Buried sand filters were developed as an alternative in order to minimize the offensive odor oftentimes associated with surface filters. These units are typically designed with 1 to 3 gallon per day per square foot loading rates intended to provide adequate detention times necessary to achieve maximum suspended solids removal.

AEROBIC LAGOONS

Aerobic lagoons have been proposed for rural areas where conventional septic systems are not possible. The design of aerobic lagoons is similar to that used for the stabilization ponds, oxidation ponds and aerobic lagoons utilized in many large wastewater treatment plants. A municipal oxidation pond will typically use a detention time of approximately 30 days. Household aerobic lagoons, due to their much smaller size and increased chance of short circuiting, are typically sized with a detention time of 100 days corresponding to a surface area of approximately 220 square feet per person and a liquid depth of 3 feet. The minimum recommended size of an aerobic lagoon is 900 square feet, with improved operation noted when a minimum size of 1,050 square feet is used. Anaerobic conditions may result in the bottom sediments (facultative lagoons) with aerobic treatment layers only present on the surface. This may lead to increased odor problems, and therefore should be avoided or closely monitored.

The effluent quality of an aerobic lagoon can be generally very good; especially in warm climates where greater than 90 percent BOD reductions may be accomplished. The unit should be preceded by a septic tank and should be located 150 to 200 feet downwind of the nearest residence, open to direct sunlight and wind. Berms and fences should be constructed surrounding the lagoon utilizing proper construction techniques including 3:1 sideslopes, a 4-foot wide top and 2 feet of available freeboard.

EVAPOTRANSPIRATION

It is estimated that there are approximately 5,000 evapotranspiration units currently in the United States. Evapotranspiration and evapotranspiration/seepage systems have been proposed as a simple solution to the widespread wastewater disposal and ground water contamination problems. Evapotranspiration systems utilize capillary action in shallow sand beds or trenches to draw liquid up towards the surface and the plant root zone where it is removed by evaporation or utilized by vegetative transpiration. An evapotranspiration/seepage system uses the limited infiltrative capacity of the soils surrounding an unlined evapotranspiration bed to provide soil absorption to aid in the elimination of the applied liquid load.

Many factors affect the rate of evapotranspiration at a particular site including the available solar radiation, temperature, elevation, relative humidity, wind speed, soil moisture availability, plant density and species distribution, and bed surface area. Additional factors which need to be considered in the design and siting of an evapotranspiration bed include the annual and seasonal temperature patterns and rainfall intensity and duration.

Evapotranspiration beds are best suited for hot, semi-arid regions. The heavy rainfalls that are typical of the Virgin Islands climate makes evapotranspiration of limited use as a sole treatment method. While a conventional soil absorption system may actually involve some degree of evapotranspiration in the removal of nutrients and liquid wastes, this impact is usually neglected in the design of soil absorption systems.

PEAT BED FILTRATION

Peat moss has proven to be effective in the removal of trace materials (copper, nickel, cobalt, and zinc) and has been successfully used in the treatment of industrial wastes. Nineteen cities in Finland use peat bogs for municipal wastewater treatment and studies have been conducted in Wisconsin regarding the use of peat bogs for the polishing of effluent from sewage lagoons and secondary treatment plants. Peatlands, peat trenches, and swamplands have been used as a main form of wastewater treatment, following pretreatment in a septic tank and aerated receiving pond, in the northern region of NW Quebec.

Studies conducted in Maine on the construction and use of Sphagnum peat beds for wastewater treatment reveals that these systems may indeed offer some benefits but will need increased study to prove their worth, and if found to be acceptable will require competent designers and installers. Peat beds display a range of hydraulic conductivities, depending upon the degree of humidification, water content, dry density, type of peat and depth of sample. The reported study utilized a 75 cm (30 inch) deep peat bed and loading rate of 1.5 cm/d (0.35 gpd/sf). The results of the study indicate that the peat bed worked satisfactorily with no problems or odors and no visible ponding of effluent.

ANAEROBIC FILTERS

Anaerobic filters have since been developed as a pretreatment device for domestic discharges and for high strength or acidic industrial wastes, and are currently receiving increased attention as an alternative treatment process designed to anaerobically treat and dentrify aerobic treatment unit effluent.

Anaerobic plug flow filters are chambers filled with a solid media which promotes fixed film and interstitial microbial growth. These chambers are usually operated in an upflow mode and can be as simple as a concrete septic tank or water-tight chamber filled with rock. Anaerobic plug flow filter systems provide many advantages to the use of aerobic filters, including the removal of organics as gases like methane, carbon dioxide and nitrogen rather than fixed as new cell material. This results in a decreased sludge volume which is 6-10 times as dense as an aerobic sludge. Additional advantages include the ability of the system to handle shock loads, the ability of the system to survive for extended periods on no load at all, an improved effluent quality transported to the soil absorption system, and low cost of operation and maintenance.

DISINFECTION

Disinfection of wastewaters can be accomplished by a variety of chemical, physical, mechanical, and radiation techniques designed to physically trap the bacteria cell or to inactivate the cell by mechanisms causing damage to the cell wall, alteration of the cell permeability, alteration of the colloidal nature of the protoplasm or inhibition of the enzyme activity. Disinfection of household wastewaters has been advocated in many states prior to surface discharge to water bodies. Simple disinfection devices which have demonstrated some reliability in domestic use include ultraviolet radiation using mercury vapor lamps and dry feed chlorination systems. Proper disinfection requires a clarified effluent as suspended solids, metals, and refractory organics interfere with the process. Because of this need for a highly purified effluent, sand filters or some other system may be necessary prior to disinfection.

SEWAGE TREATMENT FACILITIES

The preceding sections evaluate non-conventional and modified treatment processes intended to provide an alternative to the conventional septic system. Many of the treatment options discussed in the preceding paragraphs have processes which go beyond the scope of the simple subsurface septic system and would approach being classified as sewage treatment facilities. Sewage treatment facilities have been used in the Virgin Islands for many years to treat wastewater flows from urban areas housing developments, hotels, and other projects.

Sewage treatment facilities generally include primary settling followed by aerobic treatment, secondary settling, filtration, and disinfection. Effluent disposal is usually accomplished through ocean outfall, irrigation or some form of surface disposal.

DISCHARGE FROM PRIVATE SEWAGE TREATMENT PLANTS

Because of reasons outlined elsewhere in this report, it appears that the use of package treatment plants will be needed to treat sewage generated on the islands. The use of these plants then leads to the need for treatment and disposal of the outflow from them. The characteristics of this outflow is shown in the following table:

Septic System Effluent vs. Advanced Wastewater Treatment Facility Effluent Characteristics

Parameter	Influent Quality[2]	Effluent Quality[2] Septic Tank	Effluent Quality[2] WWTF[3]
BOD_5	300	170	15
Suspended Solids	300	60	<10
Total Nitrogen (as N)	45	42	<10
Ammonia-Nitrogen (as N)	12	40	< 2
Nitrate-Nitrogen (as N)	0.6	0.04	<10
Total Phosphorus (as P)	25	14	10
Fecal Coliform (coliform/100 ml)	$3x10^4$	$5x10^6$	<100

1. Measured prior to land application
2. All values in mg/l except as noted
3. Secondary and treatment followed by identification and disinfection

REFERENCES:

(1) Canter, L.W., and Robert C. Knox, Septic Tank Systems Effects on Ground Water Quality, Lewis Publishers, Inc., Chelsea, Michigan 1985.

(2) Massachusetts Division of Water Pollution Control File Data.

(3) USEPA, Alternative for Small Wastewater Treatment Systems, EPA-625/4-77-011, 1977.

During the disposal process, the effluent is either discharged directly to surface waters or ground waters. Depending on which type of discharge is selected, the method of treatment will vary. Sewage treatment facilities generally include primary settling followed by aerobic treatment, secondary settling, filtration, and disinfection. Effluent disposal is usually accomplished through ocean outfall, irrigation or some form of surface disposal.

Sewage treatment facilities have the potential to produce an effluent far superior to that produced by conventional septic tank systems. Aerobic biological treatment processes are capable of removing substantial amounts of BOD and TSS over and above that removed in the conventional septic tank. More importantly, the process is capable of nitrifying the ammonia in the wastewater to nitrate-nitrogen, which then can be removed through a denitrification process. Disinfection is also typically employee at such facilities providing significant reduction in the number of pathogenic organisms in the wastewater prior to its release into the environment.

Surface Water Discharge:

Surface water discharge will normally be a direct discharge to the ocean, ponds, streams, guts or other accumulations of waters. This type of discharge is generally associated with moderate to large waste water treatment facilities serving communities or government operated. A permit under Chapter 7, Title 12, Section 182 of the rules and regulations of the VI is needed for any surface water discharge. This will normally require at least secondary treatment of the discharge and under some circumstances additional treatment.

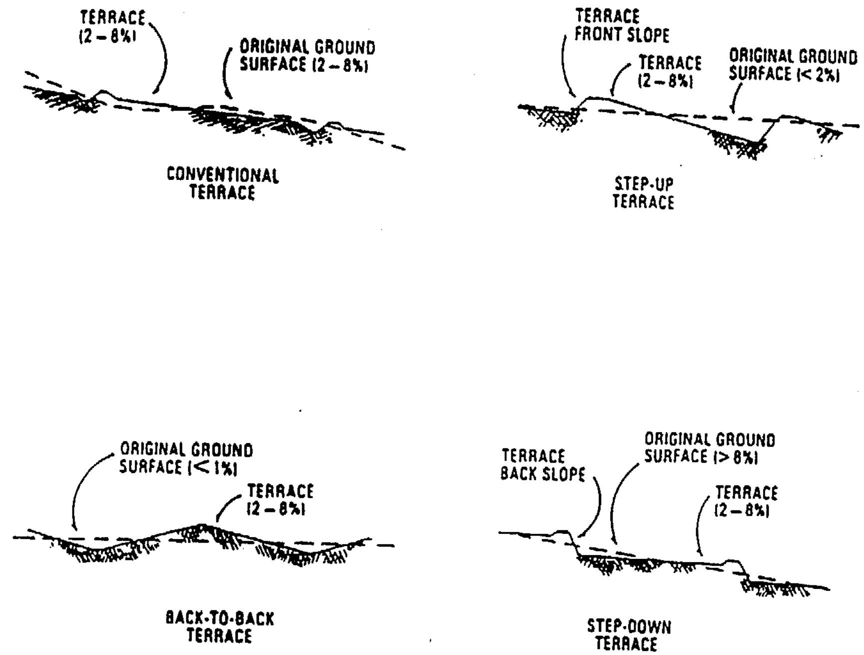
Ground Water Discharge:

Ground water discharge is accomplished by several methods to include seepage pits, leach fields, wetlands, land application and others. In these methods, effluent is applied to the soil and a combination of natural physical, chemical, and biological processes within the plant-soil -water matrix, provide the desired treatment. Again, because of conditions unique to the Virgin Islands, only one system of land application appears to be practical. This system is called the overland flow system.

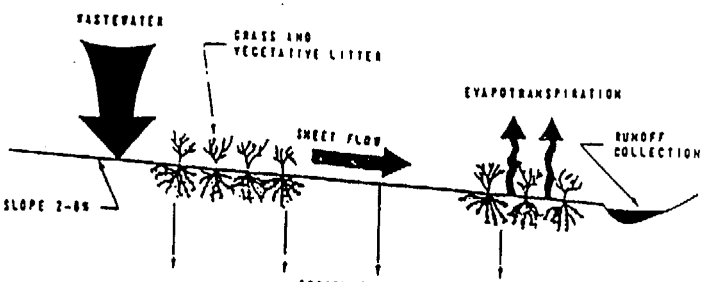
Overland Flow System:

The overland flow system functions when effluent is applied to the upper portions of sloping, grass covered fields and allowing it to flow over the vegetated surface. These grass covered fields are normally called terraces. At the bottom of the slope a series of collection ditches are used to collect the treated effluent, which can be reused or discharged to surface waters. This process is particularly suited to soils with very flow permeability, in that it is not dependent on infiltration and the treated effluent is discharged as a point source.

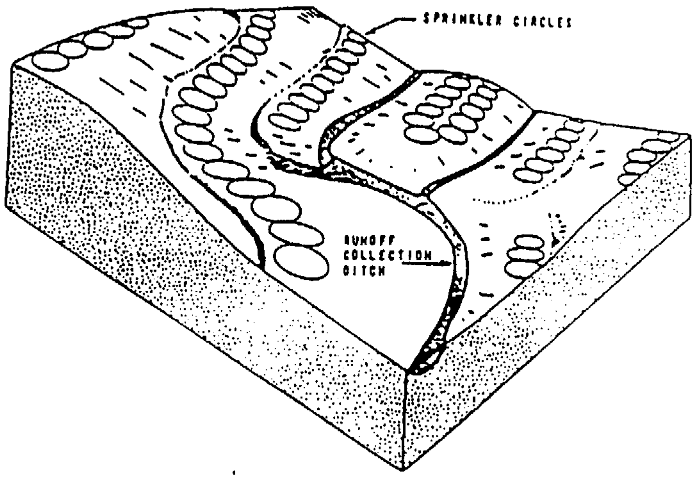
The principle objectives of this system are to achieve secondary effluent quality when applying screened raw wastewater and high levels of nitrogen, BOD, and SS removals.



TYPES OF OVERLAND FLOW TERRACES



(a) HYDRAULIC PATHWAY



(b) PICTORIAL VIEW OF SPRINKLER APPLICATION

OVERLAND FLOW

CURRENT PRACTICES

Several areas of concern have developed through the preparation of this report in which septic system practices being used in the U.S. Virgin Islands are in direct conflict with the present understanding of their design, construction, operation and the resultant effect thereof on public health issues and environmental quality. Some of these concerns may have simple solutions solvable through rule changes while others will require difficult decisions regarding restrictions on the use of septic systems in certain areas.

Design requirements for septic systems appear to be modeled after U.S. Public Health Service recommendations of 1960's vintage and have not been reviewed since the 1970's. They do not provide for the adequate sizing of system components, adequate assessment of the suitability of a site for septic system placement, or adequate separation distances from physical constraints (see Log Size); considerations which can lead to premature failure and public health risk from inadequately treated wastewater carrying pathogens being discharged to the surface (see Site Assessment) or into bedrock aquifers (see Groundwater Quality Protection).

EXISTING REGULATIONS

SEPTIC SYSTEMS

New septic systems are regulated as part of the Environmental Laws and Regulations of the Virgin Islands, Title 19, 1979. This publication describes how septic systems shall be designed and constructed along with percolation test criteria and dimensional criteria. A synopsis of the regulations are as follows:

A. Location of Sewage Systems

Location and installation of the sewage disposal system shall be such that, with reasonable maintenance, it will function in a sanitary manner and will not create a nuisance nor endanger the safety of any domestic water supply. In determining a suitable location for the system, consideration shall be given to the size and shape of the lot, slope of natural and finished grade, depth of ground water, proximity to existing or future water supplies, and possible expansion of the system.

(1) No part of the system shall be located so that surface drainage from its location may reach any domestic water supply;

(2) The lot size shall be sufficient to permit proper location, installation, and operation.

B. Septic systems or alternative systems are allowed. If a "septic tank system" is employed, it must consist of a septic tank, subsurface-disposal field, or seepage pits, or combination of the two.

C. Minimum Distances (in feet) required between septic system components and the following items:

	Septic Tank	Subsurface Disposal Field	Seepage Pits
Property Line	5	10	10
Any Domestic Water Supply	50	50*	100
Dwellings	5	10**	20
Streams	-----	25	-----
Large Trees	-----	10	-----
Seepage Pit	-----	6'	3 x dia.

* *Shall be increased per Dept. of Health recommendations where existing wells are encountered.*

** *May be reduced to 5 feet where proper drainage conditions exist.*

D. Septic Tanks

The size of septic tanks is based on the number of bedrooms, the minimum tank size being 500 gallons for a two bedroom home. The dimensions and construction must met the following standards:

(1) Tank shall be watertight construction, made of sound and durable materials, not subject to excessive corrosion or decay.

(2) Tank shall be a minimum of 33 inches wide, with a liquid depth between 4 and 6 1/2 feet.

(3) The inlet and outlet of each tank or compartment shall be baffled to provide a storage volume for scum.

(4) Access manholes shall be provided over the inlet and outlet of the tank.

E. Subsurface Disposal Field

(1) At least two percolation tests are required at different locations on the disposal field according to a prescribed method. Where fissured rock formations are encountered, tests shall be made under the direction and supervision of the Department of Health.

(2) The total bottom area of the disposal field trenches shall be based on the: (a) percolation rate of the soil and, (b) number of bedrooms in the dwelling. The minimum trench bottom area per dwelling unit shall be 150 square feet.

(3) Soils with a percolation rate over 60 minutes per inch are unsuitable except for special design with seepage pits.

(4) There shall be a minimum of two (2) disposal trenches per field and trenches shall be:

(a) 18" to 36" Wide.
(b) 18" to 36" Deep.
(c) Between 6 and 9 feet minimum spacing, center to center of trench, depending on trench width.

(5) Pipe for trenches shall be a minimum of 4 inches in diameter and shall be perforated or laid with open joints.

(6) Trench fill material shall be crushed stone, gravel, slag, clean under or similar material acceptable to the Department of Health. Fill shall extend a minimum of 6 inches below pipe and 2 inches over pipe.

(7) Trenches may be terraced to maintain proper grade and cover.

F. Seepage Pits

(1) "Use of seepage pits with septic tanks is acceptable only when such use is necessary because of soil conditions or topography and when such use is satisfactory to the Department of Health. Seepage pits shall not be used in limestone areas or in localities where shallow wells are used as a source of water supply."

(2) The size of the seepage pits shall be based on the: (a) character of the soil (i.e., sand, gravel, or sandy/gravelly clay), and (b) the number of bedrooms in the dwelling.

(3) Seepage pits are unsuitable in "heavy tight clays, hard pan, rock, or other impervious formation".

(4) Seepage pits shall be lined with brick, stone, block, or similar materials at least four inches thick laid in cement mortar above the inlet, and dray with two-to-four-inch open vertical joints below the inlet.

G. Distribution Box

A distribution box shall be constructed at the head of each disposal field for the purpose of adequately distributing flows between disposal trenches and/or seepage pits.

WASTEWATER FLOWS

On-site wastewater disposal facilities are designed on the basis of the estimated volume of wastewater flows. Sanitary wastewater is defined as wastewater discharged from plumbing fixtures into the private disposal systems that the system will experience. EPA estimates that the overall average daily wastewater flow from a typical residential dwelling is approximately 45 gal/capita/day. While the average daily flow experienced at one residence compared to that of another can vary considerably, it is typically no greater than 60 gpcd and seldom exceeds 75 gpcd. Maximum daily flows, on the other hand, are estimated by multiplying a safety factor to increase the average flow rate. The general practice in the continental United States is to use a value of 75 gallons per person per day for sewage disposal design.

In the Virgin Islands, the amount of wastewater flow is dependent upon and related to the availability and perceived cost of the water supply. During the wet season, when a household's cistern is near overflowing and more rain is expected, the water use may jump to 80 or 90 gal/capita/day. But, during a drought, when the cistern is almost empty and a load of a trucked in water is necessary, extreme water conservation methods are usually employed. The water consumption may drop to 20 to 30 gal/capita/day.

The Virgin Islands Environmental Laws and Regulations do not specify a per capita design value for wastewater flows to disposal systems. Instead, disposal fields are designed by correlating the trench seepage area with a percolation rate and the number of bedrooms served by the system. Comparing the regulation's absorption area values with similar data published by EPA, it can be inferred that the current regulations are assuming a wastewater flow of approximately 40 to 50 gallons per person per day.

LOT SIZE AND SETBACK DIMENSIONS

Current land development codes allow lots with on-site septic systems to be as small as one quarter acre in size. This practice presents two areas of concern. The first relates to the high density of development allowed on septic systems and the resultant impacts to groundwater quality. The second concern relates to the lack of sufficient land area to meet the spatial requirements of the construction of a house, cistern and septic system while maintaining appropriate separation distances, especially on sloping sites. Setback distances refer to the horizontal or lateral distance between the various components of the septic tank/soil absorption system and areas, or items of concern. For the most part, these include points of possible human contact such as cisterns or dwellings. Generally, the specified separation distances are intended to provide adequate transport time for the passage of effluent through the soil where the concentrations of contaminants are expected to be reduced by filtration, straining, physical-chemical processes, biological activity, dilution, and dispersion.

Title 19 Regulations currently require that in siting septic tanks, disposal fields, and seepage pits, certain minimum horizontal separation distances be maintained with respect to: water supply, property lines; and dwellings while the regulations specify that the ten foot separation be maintained between property line and disposal fields, no consideration is given to the fact that there may be a large difference in elevation between the septic system and the abutting property. It is not uncommon to find a disposal field placed a short distance away from the top of a one story retaining wall or a very steep slope and the septic system leaching out at the toe onto the abutting property.

BUILDING ADDITIONS

The Department of Planning and Natural Resources Permit Division reviews new septic system designs through the "Earth Change" permit application process. During this process, the Department reviews the septic tank details, drainage trench or seepage pit locations, site grading, number of bedrooms, etc. Based on the approved plans, the building and septic system are built and an occupancy permit is issued.

It appears that, once a building is constructed, any further building additions or alterations does not necessarily involve the Earth Change Permit process and therefore does not necessitate a review of the existing septic system to ensure that its size will accommodate additional bedrooms or other increases in occupancy.

INSPECTIONS

Once septic plans are approved during the Earth Change Permit Process it has been noted that many times the systems are not located as shown on the plans. Although there are many opportunities for inspection by DPNR representatives it has been noted that inspections are either not as rigorous as one might expect, or the inspections are not undertaken.

SEPTIC SYSTEM FAILURE

In the continental United States, septic system failure is generally considered to have occurred when the soil absorption system either fails to accept wastewater or fails to adequately treat the wastewater prior to discharge to the ground water.

In the Virgin Islands, many regulators consider failure of a septic system to occur only when there are complaints about sewage spilling over to abutters property or when strong odors are enough to cause neighbors to complain.

The Health Departments on St. Croix and St. Thomas have indicated between 300 and 400 septic system failures are reported on each island every year. Although failures are to be expected, these figures appear to be high with respect to the population of the islands which utilize septic systems and the likelihood that a significant percentage of failures are not reported. Public health officials attributed the high premature failure rates to the fact that: (1) construction in soils with low permeabilities; (2) improper construction; (3) small lot sizes on sloping sites; (4) the fact that there are no requirements in place for septic system upgrades when the use of an existing structure is expanded; and (5) inadequate design requirement for septic system components. Seepage pits that are discharging waste water directly to fractured bedrock are not considered to be a "failure"

Given the information acquired during the development of this report, it is estimated that the septic system failure rate is significantly higher than currently realized. The predominant cause of these failures is improper siting. Septic systems cannot operate properly in impermeable soils nor bedrock. Once a septic system is located in an area that does not have suitable soils and that system goes into failure, the only reasonable way to reduce the impact of the failure is to:

(a) provide holding tank capacity in which to store sanitary waste until the sewage can be removed by a septage hauler for disposal at a treatment facility. Due to the high cost, this option is usually only a short term solution.

(b) Limit the amount of wastewater discharged by employing water conservation techniques. Wash clothes at laundromats.

(c) Connect to public or private sewer.

POLLUTION OF GROUNDWATER

Septic systems are very efficient in removing nearly all of the contaminants present in domestic waste water when they are properly sited, designed and constructed. Use of septic systems in areas that have soil conditions which are capable of accepting and transmitting septic tank effluent through several feet of soil under unsaturated flow conditions is compatible with protecting groundwater quality for drinking water supplies as long as the density if installations is controlled to maintain groundwater nitrate-nitrogen levels below 10 mg/l. Use of septic systems which are improperly sited and constructed as well as in areas with unsuitable soil conditions have been shown to discharge pathogens to groundwater aquifers and have caused numerous disease outbreaks. The density of septic systems has been shown to have a direct relationship with the level of nitrate-nitrogen in the underlying groundwater table. Although no known studies have been conducted to date to specifically determine the fate of contaminants introduced into the environment through current practices on the U.S. Virgin Islands, the routine presence of fecal bacteria and elevated nitrate levels reported in the existing studies of the Islands aquifers clearly indicates a near certainty that existing septic system practices have already impacted groundwater quality.

PATHOGEN CONTAMINATION:

Current septic system practice in the U.S. Virgin Islands which is a primary concern with respect to potential pathogen contamination of groundwater is the construction of seepage pits or dry wells in areas with shallow soil depths over highly fractured volcanic bedrock or limestone formations. These areas comprise nearly all of the existing and/or potential building sites on St. Thomas and St. John and cover a large percentage of those on St. Croix. As these sites are also located on steeply sloping landforms, the typical homesite is created by excavating extensive cuts into the landform and spreading the excavated rubble to create a level area to construct the home and septic system. Any natural soil materials present on the site are removed or destroyed in this process. Depending on its location on the site, the seepage pit used for final disposal of the septic tank effluent is constructed either directly into the bedrock formation or the rubble derived from that formation used to create the building site.

This practice allows a direct connection for the septic tank effluent to pass directly into the bedrock aquifers without the benefit of unsaturated flow through a sufficient soil medium to effect pathogen removal. While plant uptake by root masses located within the fracture systems close to the ground surface may account for some removal of the septic tank effluent, it is unlikely that they are capable of removing the entire waste stream and saturated flow within the fracture system can result in pathogen movement into the underlying groundwater within the aquifer. This is especially true during periods of heavy rainfall events which are the primary source of recharge to the aquifers. Water levels in bedrock wells have been noted to have wide fluctuations during these events as recharge waters enter the aquifer at a rate greater than the cracks and fissures are capable of transmitting them. This results in a flushing action with rapid migration of contaminants present to the groundwater.

Alternative natural systems which have been used elsewhere to overcome conditions of shallow soils over bedrock formations primarily consist mound systems. Soil materials capable of providing suitable treatment capabilities, usually medium to coarse textured sands, are imported to the site to create the necessary separation distance between a disposal field or trench system and the bedrock formation. In order to control erosion problems, construction of these systems are typically restricted to slopes of 25% or less. These systems are not practical solutions in the U.S. Virgin Islands for the following reasons:

- Construction materials necessary to build such a system are not readily available. Sand must be imported to the Islands and, where available, is very expensive.
- Slopes of building sites typically exceed 25%.
- The spatial requirements necessary to build such a system are not provided in the current minimum lot size standards.
- The cost of constructing such a system is estimated to exceed $35,000 for new construction with the cost of retrofit to an existing developed site being much higher.

Pathogens are microscopic disease causing organisms that are indigenous to human and animal digestive tracts. They consist of certain bacteria, viruses and protozoa that are present in extremely high numbers in individuals who are either infected or are carriers of the disease and are shed through the feces of these individuals. The primary objective of septic system design and construction is to provide the treatment mechanisms necessary to effectively remove these organisms from the waste water stream before it reaches an underlying aquifer formation. Pathogens which are allowed to reach such formations pose a threat to individuals or populations who rely on them for potable drinking water sources.

A literature review conducted by Marylynn Yates and presented in Septic Tank Density and Ground-Water Contamination (Vol. 23, No. 5-GROUND WATER-September-October 1985) reports that "The consumption of untreated or inadequately treated groundwater was responsible for over one half of all the waterborne outbreaks and 45% of all cases of waterborne disease in the Unites States from 1971 to 1979. (Disease) causing agent were determined in 45% of the outbreaks. Only 11% were caused by toxic chemicals; the vast majority were caused by pathogenic (disease-causing) microorganisms. The remainder were classified as acute gastrointestinal illnesses of unknown (cause). It is believed that many of these were caused by viruses such as the Norwalk virus or rotoviruses, for which detection methods have only recently become available. Overflow or seepage of sewage from septic tanks or cesspools was responsible for 43% of the outbreaks and 63% of the cases of illness caused by the use of untreated, contaminated ground water. Thus, septic tanks represent a significant threat not only to preserving the potability of ground water, but also to human health."

Removal of pathogens from septic tank effluent by soil mediums has been widely studied and shown to be effective when the effluent is able to flow though a sufficient depth of aerobic soil under unsaturated flow conditions. The treatment mechanisms involved in this process are discussed in detail in Part 1 of this report. Simply stated, pathogens are removed from the waste stream through filtration and adsorption by soil particles. High moisture tensions present within the soil under unsaturated flow conditions retain the pathogens within the soil profile long enough for them to rendered inactive through natural die off due to hostile environmental conditions or microbial utilization by other soil organisms. Soil depth, texture, moisture content and temperature are critical characteristics in determining the effectiveness of these processes. Insufficient soil depth, coarse textured mediums, saturated flow conditions and low soil temperatures can individually or jointly minimize or obviate pathogen removal from a waste stream underneath a septic system.

The Robert S. Kerr Environmental Research Lab in Environmental Effects of Septic Tank Systems (U.S. Department of Commerce-National Technical Information Service, PB-272 702, Aug 77) reports "Whether or not pollutants moving from the tile fields through the soil reach the ground water and subsequently a water supply depends to a large extent on the type of subsurface material involved and the thickness. Figure 6 presents four common aquifer types which may transmit pollutants great distances. Conventional septic tank systems should be avoided in areas where fractured or cavernous formations, such as the bottom three rock types, are less than a few feet below the bottom of the absorption trench. Such rock types provide a minimum of the three major processes necessary to retard or control the movements of pollutants--filtration, adsorption and microbial degradation. Generally, the fissures and channels are too large to provide significant filtration. The detention time and active surface areas available are not great enough for appreciable adsorption or microbial degradation to occur." It is important to note that volcanic rock (the most prevalent rock type in the U.S. Virgin Islands) comprises aquifer type 4 in the reference figure and carbonate rock (the Kingshill Formation on St. Croix) comprises aquifer type 2.

Once allowed to enter a saturated aquifer, pathogens have been shown to survive and remain active for extended periods of time. In Survival and Movement of Fecal Indicator Bacteria in Soil under Conditions of Saturated Flow (Journal of Environmental Quality, Vol.7,no.1, 1978) Hagedorn et.al. studied the movement and survival rates of *Streptococcus faecalis* and *Escherichia coli* under saturated soil conditions. Inoculations of both bacteria were introduced into saturated soil conditions and the rate of movement and survival were monitored through sampling wells place various distances from the inoculation point. They report "Three concepts of major importance can be derived from the data on the presence of the indicator bacteria in the test wells. First, the bacteria moved long distances in a relatively short period of time in a soil with a surface gradient of only 2%. Second, the populations of indicator bacteria in the various wells reached maxima during intervals closely associated with the rise of the water table following major rainfall periods. Third, both *E. coli* and *S. faecalis* survived in appreciable numbers in the saturated soil throughout a 32 day sampling schedule, and with the wet and cool soil conditions, it is highly probable that their survival would extend considerably beyond 32 days."

Keswick and Gerba conducted a literature review of the then available information on virus contamination of groundwater and reported their findings in Viruses in groundwater (Environmental Science & Technology, Vol. 14, 1980). Although little was known about virus removal and transport mechanisms at the time, one field study showed virus survival for at least 28 days in groundwater and laboratory experiments showed virus survival in excess of 200 days in drinking water. They suggest that "Since the effects of sunlight is eliminated and the temperature is lower, even longer survival times would be probable in groundwater". In 1982 Keswick, Gerba, et.al. published the results of a study titled Survival of Enteric Viruses and Indicator Bacteria in Groundwater, (J. Environ. Health, A17). "In summary, it was found that human enteric viruses survive longer than 24 days in groundwater (length of study)."

NITRATE CONTAMINATION:

Second in concern to bacterial and viral contamination from septic systems is the movement of nitrate-nitrogen into the groundwater. Excessive amounts of nitrate nitrogen in drinking water can lead to methemoglobinemia, a condition which prevents the normal uptake of oxygen in blood of young infants. In order to reduce its risk the Environment Protection Agency has established a maximum contaminate level of 10 mg/l for nitrate-nitrogen in public drinking water supplies. In addition nitrate-nitrogen has been implicated in the formation of carcinogen in the digestive system (Cogger, On-site Septic Systems: The risk of groundwater contamination, Journal of Environmental Health, Vol. 51, No. 1, September/October 1988).

Cogger, Kerr, Yates and others report numerous references in which septic system practices have resulted in local and regional nitrate-nitrogen contamination of groundwater supplies. Long Island, Cape Cod and the Delaware coastal plain are the most notable areas which have received extensive study. These studies demonstrate that nitrate can reach unacceptable levels in groundwater beneath soils that are otherwise suitable for treating septic tank effluent (Cogger). Kerr states that "The most important parameter influencing regional contamination from septic tank systems is the density of these facilities in a given area, although geology, depth to water table, and climate may effect the nature and degree of the problem".

Nitrate-nitrogen is the end product of microbial mineralization of nitrogen rich organic products as wastewater passes through an aerobic biologically active soil formation (see discussion in Part 1). This process occurs in the soil treatment zone underneath a functioning septic system as well as in upper soil horizons at wastewater land application sites and results in a nearly complete conversion of organic nitrogen to nitrate-nitrogen. Once formed nitrate-nitrogen is a very stable soluble compound that is not affected by normal soil treatment mechanisms and readily migrates into the underlying water table. Mechanisms which are capable of reducing nitrate-nitrogen concentrations in a waste stream include plant uptake, microbial denitrification, and dilution. Nitrate-nitrogen is a fertilizer and can be readily used by plants. Plant uptake can account for nitrate-nitrogen reduction at land application sites where nitrate formation occurs close enough to the ground surface to allow contact with plant root masses. Plant uptake, however, is not likely to have an appreciable affect in reducing nitrate-nitrogen concentration underneath a functioning septic system (Cogger). Microbial denitrification can result in reductions when nitrate-nitrogen passes into an anaerobic soil condition which has a suitable carbon energy source to allow the denitrification process to occur. This process typically happens in soils with high groundwater tables and is not a significant factor in soils with no or very deep water tables as are typically found in the U.S. Virgin Islands. Dilution with groundwater is the most commonly used approach to control nitrate-nitrogen concentrations. This method requires controlling the density of septic systems within a given area to levels at which the groundwater recharge within the area is capable of diluting the nitrate-nitrogen concentrations generated by the septic systems to concentration below 10 mg/l. When density of development becomes too high, dilution no longer is an effective means to control nitrate-nitrogen concentrations (Cogger).

One typical approach used to control septic system density is through minimum lot size requirements designed to insure that the yearly volume of rainwater infiltration which occurs on the lot is sufficient to dilute the nitrates generated by the septic system to 10 mg/l or less. Several mathematical models have been developed to estimate the land area necessary to accomplish this approach and/or to estimate an appropriate density of development within a given area. One such model, A Procedure To Determine Optimum Density For Homes Using Individual Wastewater Treatment Systems Based On Nitrogen In Ground Water Recharge, was developed by the consulting firm of Geraghty & Miller, Inc and others through the National Association of Home Builders-National Research Center. This method has been applied to some areas in the northeast and has resulted in minimum lot size requirements of between 3/4 and 2 acres depending on soil/slope conditions present on the lot. Climatic conditions in the U.S. Virgin Islands, however, are considerably different than in the northeast. Although average annual rainfall is similar, the amount of recharge to the water table is drastically less, estimates by the U.S. Geological Society result in about 1.5 inches per year. Applying this information through the referenced model results in lot size requirements for the U.S. Virgin Islands of approximately 7.25 acres per home in order to control nitrate-nitrogen contamination (figure GW1). Inputs to the model to arrive at this figure assume an average occupancy rate of four individuals per home using 55 gallons of water per day and generating 9 pounds of nitrogen per year each (nationally recognized standards). In addition the average annual recharge rate of one inch per year is assumed to occur uniformly over the landscape and the nitrate-nitrogen concentration in the homes drinking water supply is 0 mg/l. While refinements to these assumptions would need to be made in order to implement minimum lot size requirements in the U.S. Virgin Islands for the purposes of controlling nitrate contamination, it is obvious that the land area required per lot would not be realistically implementable.

POLLUTION OF SURFACE WATER

Fresh water resources of the U.S. Virgin Islands are ephemeral in nature. Due to the Islands climate and hydrogeology, groundwater tables rarely intersect and discharge to the ground surface with the primary exception being in areas adjacent to coastal embayments. Fresh water resources consist of intermittent stream channels, locally known as guts, and surface impoundments. These features provide important functions by collecting, storing and transmitting surface water runoff from major storm events. Runoff which is able to be stored in the guts and impoundments are important water sources for irrigation/ agricultural uses as well as a major source of groundwater recharge to underlying aquifers. Excess runoff which is discharged to coastal embayments supports their unique ecosystems. As these resources serve as groundwater recharge sources and are generally not receptors for groundwater discharge, the operation of septic systems within their catchment areas through practices that do not result in surface discharge of inadequately treated waste water is not likely to cause threats of nonpoint source pollution. Operation of septic systems through practices which result in high densities of failures, however, is a concern with respect to nonpoint source pollution. Pathogens and nutrients present through the surface discharge of inadequately treated waste water are readily incorporated within the runoff generated by heavy storm events and are flush into surface water systems. While this may not pose long therm threats to the guts and impoundment areas which are ephemeral and dry most of the time, impoundments which have the ability store water on a more permanent basis and the coastal water resources which are receptors of pollutant laden runoff are at risk. The areas of particular concern with respect to this issue are densely developed areas in the alluvial and deep volcanic parent materials with montmorillonite clay mineralogy on the Island of St Croix. These areas have large catchment areas and are reported to have the highest incident of septic system failures.

As previously stated, Montmorillonite clays exhibit a very high shrink/swell capacity and can absorb water at a rate of twenty to thirty times their own weight. Percolation tests conducted as part of this study in one such soil, Hogensborg, clearly demonstrated that a conventional percolation test could greatly over estimate these soils ability to accept and transmit septic tank effluent. The Hogensborg accepted water at a uniform rate of 10 min/in for several hours and would appear to have stabilized, meeting the criteria for a conventional test. In fact this soil continued to accept water 16 hours before enough water had been applied to satisfy the montmorillonite clays absorption capacity, at which point the swelling of the clays closed reduced the flow paths available for water movement to such an extent that no measurable infiltration was occurring thereafter. The continuous application of septic tank effluent to these soils will have the same effect, resulting in failure and surface discharge. Continuing to allow the construction of septic systems in these areas will increase the nonpoint pollution threat from surface water runoff generated in these areas.

Coastal waters are the most abundant and valuable surface water resources of the U.S. Virgin Islands. They consist of beaches, salt marshes, salt ponds, mangrove swamps, coastal embayments and shallow reefs distributed all along the Islands shorelines. Many of these resources have unique environments that rely on fresh water sources supplied by groundwater and surface water discharges as well as their adjacent marine environments. As nitrogen is the limiting nutrient controlling excessive aquatic plant growth in these environments, the concentration of nitrogen compounds in the fresh water resources discharging to these environments is a primary concern of management programs to abate and control nonpoint source pollution. In 1986 the U.S. Geological Service reported that the median nitrate-nitrogen concentration of groundwater samples collected from coastal embayment aquifers 0.2 mg/l. Although this is within the range considered to be naturally occurring, the higher levels of nitrate-nitrogen reported in the groundwater clearly indicates that coastal resources whose catchment areas are currently developed or are slated to be developed with densely placed septic systems are at risk. This is further demonstrated by the 4.9 mg/l of nitrate-nitrogen concentration reported in a sample collected from the coastal embayment aquifer adjacent to Cruz Bay on St. John in 1984 by the U.S.G.S..

"Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Water" (EPA-840-3-92-002 January 1993) issued by the Environmental Protection Agency recognizes the threat of nitrogen contamination to coastal waters from septic system practices and offers general management recommendations to reduce this threat from septic system practices for new systems as well as from existing operating systems. Recommendations for new systems that are important considerations in protecting the U.S. Virgin Islands coastal resources include the following:

- Insure that new On-site Disposal Systems (OSDS) are located, designed, installed, operated, inspected and maintained to prevent the discharge of pollutants to the surface of the ground and to the extent practicable reduce the discharge of pollutants into groundwaters that are closely hydrologically connected to surface water.

- Direct placement of OSDS away from unsuitable areas and to ensure that they are designed or sited at a density so as not to adversely affect surface water or groundwater. Unsuitable areas include ... areas overlying fractured rock that drains directly to groundwater... Establish protective setbacks

- Where conditions indicate the nitrogen limited surface waters may be adversely affected be excess nitrogen loading from groundwater, require the installation of OSDS that reduce total nitrogen loadings by 50 percent...

Recommendations for managing existing operating systems include inspection programs to insure proper operation and maintenance as well as replacement and/or retrofit of OSDS components that reduce total nitrogen loading.

All of the discussions and arguments presented in the sections on pollution of groundwater by pathogens and nitrates as the result of current septic system practices in the U.S. Virgin Islands are equally applicable to the issue of nonpoint source pollution to coastal waters. Although the Coastal Zone Management program of the U.S. Virgin Islands has established low density and moderate density zoning districts adjacent to many of the Islands Sensitive Coastal resources, it is unlikely that they will be able to appreciably reduce the threat of nitrogen impacts to these resources from septic systems given the minimal amount of rainwater infiltration available on the Islands for dilution. The same is true when considering the use of denitrification systems as alternatives.

PERCOLATION TESTS

The Environmental Laws and Regulations of the Virgin Islands, Title 19, requires that percolation tests be performed in at least two different locations on the disposal field.

The percolation test, often simply called the perc test, is a measure of a soil's ability to drain or "percolate" water into and through the soil. The basic method of conducting the percolation test is to dig or auger a hole in the soil 6 to 12 inches in diameter to the depth of the proposed soil absorption system. Water is poured into the hole to a depth greater than 12 inches and allowed to drain. This procedure is repeated until the rate at which the water level drops is more or less constant. The hole is then refilled to a depth greater than 12 inches and the amount of time it takes for the water level to drop one inch is determined. The percolation rate, reported in minutes per inch, is used as a determination of the suitability of the soil for absorbing septic tank effluent and for determining the size of the leaching structure.

The clay soils in the Virgin Islands make percolation tests very difficult to perform. The clays are typically so dry and well-structured that initial percolation rates are in the range of porous sands and gravels (less than 10 minutes per inch). Other contributing factors to the quick perc rates are worm/insect larvae holes, roots, and the shallow depth to fractured bedrock. Only after constant refilling of the hole will there be a gradual swelling of the clay particles and a decelerating perc rate. There are soils such as Hogensborg on St. Croix, that after hours of soaking, will become so impermeable there is no measurable drop in the hole.

The small size of the disposal fields that have been constructed in areas of clay soils indicate that one of the following is occurring:

a) Percolations are being performed in a way that does not allow the clay particles to swell, therefore, do not approximate wet soil conditions, or

b) Percolation tests are not being performed t all and the perc rates and disposal field sizes are based on past practice.

RECOMMENDATIONS

RECOMMENDATION #1

Begin the process of ending the construction of septic systems that discharge septic tank effluent into the ground. This can be accomplished by enforcing the existing U.S.V.I. regulations as they are now written.

Discussion:

The original intent of this study was to find ways to improve upon the existing septic system regulations to bring them into compliance with the usual standards for design and construction of on-site disposal of sewage effluent. The strategy in performing this study was to assume that subsurface soil absorption (disposal trenches, beds, seepage pits) is the preferred on-site disposal option because of its reliability with a minimal amount of maintenance. The process was then to analyze the soils, topography, geology, and other characteristics of the Islands so that the regulations could be customized to fit the specific circumstances. In those areas where the site characteristics are unsuitable for soil absorption systems, alternative methods would be investigated as a last resort for on-site disposal since these alternatives are typically the most costly to construct and require a great deal more maintenance and supervision than soil absorption systems.

Now that the analysis of the Islands characteristics is completed, it has been found that the vast majority of the Islands' land areas are unsuitable for soil absorption systems. It has also been found that thousands of the septic systems currently in operation are located in the areas that are inappropriate for subsurface disposal and represent not only a hazard to the environment, but more importantly, a risk to the public's health.

The U.S.V.I. Title 19 Regulations contain some very important passages that, if interpreted properly, can be used as a means to bring about the necessary change in regulating septic system construction. These paragraphs are discussed as follows:

Seepage Pits:

Title 19: 1404-92. Seepage Pits Use and Location:

"Use of seepage pits with septic tanks is acceptable only when use is necessary because of soil conditions or topography and when such use is satisfactory to the Department of Health."

This particular regulation is the caveat that allows developers to construct septic systems on the Island's steep hillsides, where shallow clay soils are underlain by fractured bedrock. It has been demonstrated (refer to section on Ground Water Quality) that the channels and fissures in fractured rock do not provide the filtration and absorption required to treat sewage before it reaches the groundwater. DPNR and the Department of Health can essentially bring this practice to an end by simply recognizing this hazard and mandating that it is no longer acceptable.

Once the option of seepage pits is unavailable, there re no reasonable alternative soil absorption systems that can be reasonably constructed on all hillsides due to the steep slope, small lot sizes, and cost constraints.

Percolation Tests:

> Title 19: 1404-92. Percolation Tests: Paragraph 4:
>
> "(4) . . . Because many seasonal factors affect the results of percolation tests, judgement is required in analyzing these results. If the tests are not conducted during a wet season they should be repeated until the moisture conditions of the soil approach those obtaining during the wet season. In no case shall tests be made in filled . . .ground. Where fissured rock formations are encountered tests shall be made only under the direction and supervision of the Department of Health."

The current practice of constructing relatively small leaching areas in some of the impervious or slightly pervious clay soils leads one to infer that the required percolation tests are either not being performed or they are being performed improperly. It is extremely important that all percolation test holes be soaked for at least 20 hours before measuring the percolation rate. Automatic siphons or float valves should be used to ensure the hole is always kept full during the soaking period. It is imperative that the soil be allowed to soak for a sufficiently long period of time to allow the soil to approach wet season moisture conditions and the conditions it will experience if a septic system is installed in it.

Percolation test should not be performed in areas where there is less than four feet of naturally occurring soils above the bedrock. Even though these soils may be somewhat pervious, there is not enough depth of soil to properly separate the bottom of in-ground leaching trenches from the top of fissured bedrock.

RECOMMENDATION #2

Extend the municipal sewage collection system and treatment plant capacity to all populated areas.

Discussion:

Realistically, if a non-rural community does not have the soils, geology, or other characteristics that allow the use of low-cost, soil absorption septic systems, the best proven alternative is to create or expand municipal sewers and treatment plants. The Public Sewer System is particularly well-suited for the Virgin Islands for the following reasons:

a) Much of St. Croix and most of St. Thomas is densely populated and new development continues to cause increases on the population of all three islands.

b) The physical areas of each of the Islands is small by mainland standards. St. Thomas and St. John are no larger than many small mainland towns. St. Croix is only the size of some of the smallest mainland counties. The construction of an island-wide sewer network is no great feat considering the small land areas involved.

c) Most of the developed land and much of the undeveloped land has already been subdivided into small, quarter-acre and half-acre lots. Municipal sewerage is the only option that can adequately deal with environmental effects of these dense developments. It is too late to institute proper land planning measures to account for the land areas required for individual sewage treatment systems.

d) Municipal sewerage is the only option that allows the government the ability to eliminate the problems with existing septic systems. Even if regulations could be adopted so that all new septic systems would operate safely, those same regulations would do nothing to address the non-conformance of existing septic systems. It is extremely difficult (some would say impossible) to impose new rules and regulations on the present population and force them to upgrade their existing systems when poor soils, steep slopes, or other site limitations exist. Tieing into a municipal sewer, however, is a common and politically acceptable method of undoing past problems and mistakes.

e) Municipal sewerage is typically the most economical alternative for urban areas. If treatment capacity exists and only sewer extensions are necessary, costs can run in order of $5,000 per four-member household. If both sewer and new treatment facilities are required, these costs can increase to $10,000 to $20,000 per four-member household. Many times federal funds are available to offset much of these costs, particularly when potential health problems can be documented.

f) Municipal sewage treatment systems are a proven technology. Treatment plants are servicing the major population centers on all three Islands. Although there are problems inherent in treating and disposing of large quantities of sewage, at least the problems can be defined, addressed, and resolved in a logical manner. Compared to the situation where thousands of individual on-site sewage treatment systems are being operated and maintained by the average homeowner one can appreciate the rationale for large scale treatment works. New and innovative technology are more easily developed for larger sewage flows then individual homes, making the alternatives greater for municipal systems.

RECOMMENDATION #3 - Private Sewage Treatment Plants (3-part recommendation)

3A) In those areas that are remote from municipal sewer, require developers to construct privately owned sewage treatment plants (STPs) similar to the facilities in use at the major resorts.

3B) Require that all privately owned sewage treatment facilities be operated and maintained by certified treatment plant operators that are employees of the VI government.

3C) Allow developers the option of providing sewer and the funds for expansion of municipal STPs in lieu of constructing private STPs.

Discussion:

Currently, private community sanitary treatment plants (STPs) are usually owned and operated by a hotel and condominium developments. The EPA has observed that typically these associations are notoriously poor managers of community septic systems (USEPA, 1977). Regulators therefore generally require appropriate assurances that the system will be properly operated and maintained before a permit or approval is issued (USEPA, 1977).

Publicly owned and managed community on-site STPs serving small residential developments have been encouraged by the United States Environmental Protection Agency (USEPA) as effective, environmentally sound, yet less expensive alternatives to traditional sewage treatment plants, especially in rural and suburban growth areas (Train, 1976; Staudt and Niehaus, 1982). EPA has encouraged public ownership of such systems because of the problems inherent in private ownership, which include lack of individual responsibility for a failed system, improper and inadequate maintenance, improper disposal of household wastes, and lack of alternative sources should the system fail (USEPA, 1988). When appropriately sited, designed, installed and maintained, multi-user systems have met with a high degree of success in many situations.

RECOMMENDATION #4

Create a program to provide a method of assuring that public and private sewage treatment plants (STP) or innovative systems constructed, are operated and maintained properly using the following approaches:

- Require all STPs and alternative systems be designed by a licensed sanitary engineer and that the design engineer inspect the construction to certify that the plant meets all the requirements of the USVI regulations and permit conditions.
- Create a formal training course for STP operators that leads to STP operator certification. Require that all operators of public and private STPs be certified. Establish licensing fees, study guides and exam requirements.
- Require a guarantee of permanent maintenance for private STP or innovative system owners.
- Establish a program of developing a set of enforceable standards concerning effluent testing including a strict schedule of sampling and testing by certified laboratories.

V
MARINAS, BOATING AND HYDROLOGIC MODIFICATION

** Paper not available at time of printing.*

HOW TO MINIMIZE POLLUTION FROM RECREATIONAL BOATING

Lynne H. MacDonald

Virgin Islands Marine Advisory Service, University of the Virgin Islands, St. Thomas, Virgin Islands 00802

INTRODUCTION

Section 6217 of the Coastal Zone Reauthorization Act of 1990 (CZARA) requires states and territories with federally approved coastal zone management programs to develop and implement Coastal Nonpoint Source (NPS) Pollution Control Programs. Requirements for state and territory programs are described in the ***Coastal Nonpoint Pollution Program: Program Development and Approval Guidance*** developed by the U.S. Environmental Protection Agency (EPA). One component that these programs must address is NPS pollution from Marinas and Recreational Boating.

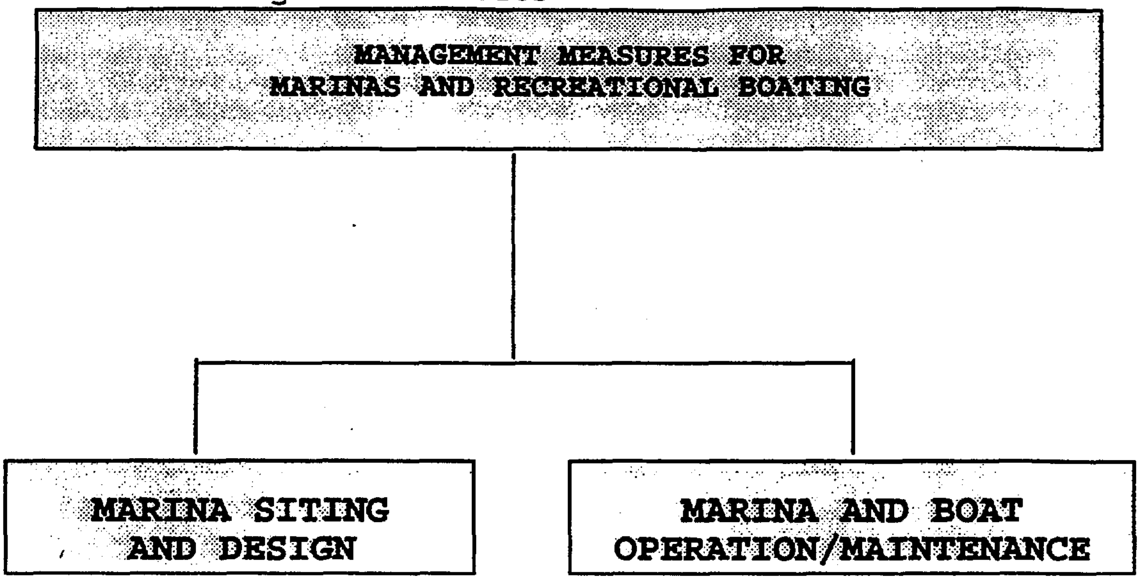
The ***Guidance*** for "Marinas and Recreational Boating", as with the guidance for the other four categories of NPS (Agriculture, Forestry, Urban, and Hydromodification), identifies *management measures* to prevent or reduce NPS pollution, or to prevent pollutants from reaching ground or surface waters. The *management measures* are intended to restore and protect coastal waters through the use of various *management practices*. A state or territory's NPS Control Program must specify the *management measures* it will implement and these measures must conform with the ***Guidance***. The *management practices* a program uses to address the specific *management measures* do not need to be specified; any one or combination of the practices provided by the ***Guidance*** can be incorporated into a program or other, equally effective practices can be used.

The use of a "specific measures, variable practices" approach to address NPS gives states and territories much needed flexibility to ensure that each program meets the needs and circumstances of a particular area. As is an all too familiar problem in the Virgin Islands, inflexible legislation and regulation can be extremely burdensome and equally ineffective. The high degree of flexibility inherent in this program allows for "tailor-made" NPS control programs that still conform with the Guidance.

MANAGEMENT MEASURES

The *management measures* for Marinas and Recreational Boating are divided into two categories: **Siting and Design Management Measures**; and, **Operations and Maintenance Management Measures** (fig. 1). The measures apply to:

Figure 1. Categories for Marina and Recreational Boating Management Measures



- Any facility that contains 10 or more slips, piers where 10 or more boats may tie up, or any facility where a boat for hire is docked;

- Boat maintenance or repair yards that are adjacent to the water;

- Any Federal, State, or local facility that involves recreational boat maintenance or repair that is on or adjacent to the water;

- Public or commercial boat ramps;

- Any residential or planned community marina with 10 or more slips; and,

- Any mooring field where 10 or more boats are moored.

Management measures for marinas are applicable to facilities and shore-based services that support recreational boats and boats for hire; they do not address specific boats except to the extent that a marina can adopt practices that apply to boats in their facility. Also, the management measures for siting and design apply to new facilities and to expanding facilities if there is potential for the expansion to impact water quality and important habitat.

Siting and design management measures are shown in table 1.

The next speaker, Ms. Nathalie Peter of the National Oceanic and Atmospheric Administration (NOAA) will be discussing "Marina Siting and Design to Minimize Pollution" and so I won't go into this any further.

Table 1. Siting and Design Management Measures

SITING AND DESIGN MANAGEMENT MEASURES
MARINA FLUSHING
WATER QUALITY ASSESSMENT
HABITAT ASSESSMENT
SHORELINE STABILIZATION
STORM WATER RUNOFF
FUELING STATION DESIGN
SEWAGE FACILITY

Table 2 lists the *Management Measures* and each measures' objective(s) for "Marina and Boat Operation and Maintenance". To achieve each management measure's objective, practices can be implemented at existing and new or expanding facilities.

The management practices that are included in the ***Guidance*** are shown in table 3. While the management measures of a state or territory's plan must be specified and consistent with those of the Guidance document, the actual practices used to achieve these measures do not. The practices listed can be used individually, or in combination to reduce or control nonpoint source pollutants. As I mentioned earlier, these practices are not limited to those shown; others that may be more effective or appropriate for unique situations or circumstances can be used.
The practices listed in table 3 are all relatively simple and inexpensive to implement. There are many operational or procedural practices, such as providing special waste receptacles for certain wastes, or designating specific areas for maintenance. A number of these management practices are designed to education and inform user groups about each management measure, and so gain compliance with the practices through increased understanding and awareness of NPS problems and solutions.

Table 2. Management Measures and Objective(s) for Marina and Boat Operation and Maintenance

MARINA AND BOAT OPERATION AND MAINTENANCE MANAGEMENT MEASURES
SOLID WASTE Properly dispose of solid wastes from operation, cleaning, maintenance, and repair of boats to limit entry of solid wastes to surface waters. **FISH WASTE** Promote sound fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste. **LIQUID MATERIAL** Provide and maintain appropriate storage, transfer, containment, and disposal facilities for liquid material, such as oil, harmful solvents, antifreeze, and paints, and encourage recycling of these materials. **PETROLEUM CONTROL** Reduce the amount of fuel and oil from boat bilges and fuel tank air vents entering marina and surface waters. **BOAT CLEANING** For boats that are in the water, perform cleaning operations to minimize, to the extent practicable, the release to surface waters of (a) harmful cleaners and solvents, and (b) paint from in-water hull cleaning. **PUBLIC EDUCATION** Public education/outreach/training programs should be instituted for boaters, as well as marina owners and operators, to prevent improper disposal of polluting material. **MAINTENANCE OF SEWAGE FACILITIES** Ensure that sewage pumpout facilities are maintained in operational condition and encourage their use. **BOAT OPERATION** Restrict boating activities where necessary to decrease turbidity and physical destruction of shallow-water habitat.

Table 3. Management Practices for Marina and Boat Operation and Maintenance.

SOLID WASTE MANAGEMENT PRACTICES
- Perform boat maintenance/cleaning above the waterline in such a way that no debris falls into the water.
- Provide and clearly mark designated work areas for repair/maint.
- Clean hull maintenance areas regularly.
- Perform abrasive blasting within spray booths or other enclosures.
- Provide proper disposal facilities (dumpsters/covered bins).
- Provide facilities for recycling of appropriate materials.

FISH WASTE MANAGEMENT PRACTICES
- Establish fish cleaning areas.
- Issue rules governing fish cleaning operations.
- Educate boaters on the importance of proper fish cleaning.
- Implement fish composting where appropriate.

LIQUID MATERIAL MANAGEMENT PRACTICES
- Build curbs, berms, or other barriers around areas used for the storage of liquid material to contain spills.
- Separate containers for the disposal of waste oil, waste gasoline, used antifreeze, and waste diesel, kerosene, and mineral spirits should be available and clearly labelled.
- Direct marina patrons as to the proper disposal of liquids.

PETROLEUM CONTROL MANAGEMENT PRACTICES
- Use auto shut-off nozzles and promote the use of fuel/air separators on air vents or tank stems to reduce spillage.
- Promote the use of oil-absorbing materials in the boats' bilges; examine and replace as necessary. Dispose/recycle accordingly.

BOAT CLEANING MANAGEMENT PRACTICES
- Wash hulls above waterline by hand. Where feasible, remove boat from the water and clean where debris can be trapped and properly disposed of.
- Use phosphate-free and biodegradable detergents. Don't overuse.
- Discourage the use of cleaners containing ammonia, sodium hypochlorite, chlorinated solvents, petroleum distillates, or lye.
- Do not allow in-water hull scraping or paint removal underwater.

PUBLIC EDUCATION MANAGEMENT PRACTICES
- Signage
- Recycling/Trash Reduction Programs
- Pamphlets or Flyers, Newsletters, Inserts in Billings, etc.
- Meetings and Presentations

MAINTENANCE OF SEWAGE FACILITIES MANAGEMENT PRACTICES
- Arrange maintenance/service contracts for pumpout facilities.
- Develop regular inspection schedules.
- Maintain a dedicated fund for pumpout station repair and maintenance (for Government-owned facilities).
- Mandate pumpout use and specify penalties for failure to comply in slip lease agreements.
- Put dye tablets in holding tanks to discourage illegal disposal.

BOAT OPERATION MANAGEMENT PRACTICES (applies to boating only)
- Exclude motorized vessels from areas that contain important shallow-water habitat.
- Establish and enforce no-wake zones to decrease turbidity.

PUBLIC EDUCATION

It is apparent from the listed practices that public education is an important component of the *management measures*. Not only is "Public Education" a specific *management measure* -- a required part of any program -- there is also an education-related practice associated with virtually all of the other measures.

Public participation and involvement in developing, implementing and continuously improving a nonpoint source reduction program is imperative for it's success. A Public Education/Information campaign must be the very first step in this process at the territory-level. A program cannot be effectively put into place without the awareness, cooperation and assistance of the community.

CONCLUSION

Many diverse sources of pollutants from marina and recreational boating operation and maintenance can be eliminated or reduced through the use of some very simple, economical means. The *management measures* and *practices* to control NPS pollution from recreational boating are direct and inexpensive. Small improvements in water quality within a marina or bay can be achieved through the implementation of any of these; a comprehensive program incorporating a number of practices can result in significant improvements in marina water quality.

The key to a successful NPS Control Program is public education and involvement in the entire program development and implementation process. With increased public awareness through participation and education, the *management practices* that are put into place can effectively minimize nonpoint source pollution from recreational boating.

MARINA SITING AND DESIGN TO CONTROL NONPOINT SOURCE POLLUTION

Nathalie Peter
National Oceanic and Atmospheric Administration
Office of Ocean and Coastal Resource Management
Silver Spring, Maryland

Marinas and recreational boating are increasingly popular uses of coastal areas and an important means of achieving coastal access. The Virgin Islands, known as the "Charter Capital of the World," has a large number of resident and transient vessels throughout the year. There are 20 marinas in the Virgin Islands. In 1991, DPNR registered 4,044 vessels and issued 719 mooring permits. According to the 1992 Strickland/Quinn report on marine facilities, 70% of the marine community that were surveyed noted the significant relationship that exists between the health of the marine environment and the success of their businesses.

When marinas are poorly sited and designed, they pose a nonpoint source (NPS) pollution threat that can affect public health and marine ecosystems. Because marinas are located right on the water's edge, there is often no buffering of the release of pollutants to the sea. Adverse environmental impacts can include:

- poorly flushed waters with low dissolved oxygen and increased petroleum hydrocarbons, pathogens, and metals.
- pollutants transported in storm water runoff from parking lots, roofs, and other impervious surfaces.
- physical alteration or destruction of wetlands and other bottom communities during construction and operation.
- pollutants generated from boatyard and marina operation and maintenance activities that contaminate bottom sediments. For example, copper is a major contaminant because of its use in antifouling paints.
- shoaling and shoreline erosion.

There are numerous territorial and federal regulatory programs that apply to marinas. Today, however, I will concentrate on the 6217 Nonpoint Source Pollution Control Program that Congress included in the 1990 CZMA Reauthorization Amendments. It applies to all states and territories with approved Coastal Zone Management Programs (CZMPs). Most of the material in my presentation comes directly from the marinas chapter of Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters (6217 Guidance), released jointly by EPA and NOAA in January 1993.

Management measures are defined as:

> economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives.

Fifteen Marina Management Measures, classified as "Siting and Design" or "Operation and Maintenance" Management Measures, are included in the Guidance. ~~These~~ Marina Management Measures are comprehensive in their coverage of sources of nonpoint pollution associated with marinas.

The following operations and facilities are covered by the 6217 Marina Management Measures:

- piers and marinas with 10 or more slips;
- any facility where a boat for hire is docked;
- boat maintenance or repair yards;
- public or commercial boat ramps;
- residential or planned community marinas with 10 or more slips; and,
- any mooring field where 10 or more boats are moored.

All of the following siting and design management measures apply to new and expanding marinas. In addition, the storm water runoff management measure applies to existing marinas and boatyards for at least the hull maintenance areas.

A. Flushing Management Measure

The first management measure is the marina flushing management measure which is to be applied to new and expanding marinas. it is to **" [S]ite and design marinas such that tides and/or currents will aid in flushing of the site and renew its water regularly."**

If a marina does not flush properly, there is a potential for waters to stagnate and for pollutants to concentrate to unacceptable levels in the water and/or bottom sediments, resulting in impacts to the biological resources. Flushing time can range from several hours to possibly several weeks, depending upon the location of a marina in a waterbody and its configuration.

In the Virgin Islands, flushing is primarily due to (1) the movement of the tidal prism and currents in and out of a marina waterbody and (2) wind-driven circulation.

The degree of flushing necessary to maintain water quality in a marina should be balanced with safety, vessel protection, and sedimentation. Flushing guidelines can be developed for different regions and different conditions. For example, in Florida where tidal range does not exceed 1 meter, a flushing reduction of 90% over a 24 hour period has been recommended.

Practices

In addition to specifying management measures, the §6217 Guidance also provides management practices that can be applied successfully to achieve the management measures. However, the application of these practices needs to be tied to the NPS pollution source, the specific site, and the climate. This is especially true in the Virgin Islands where the climate is tropical; the topography is steep slopes; soil cover is thin; and suitable shoreline is limited and costly. While most of the siting and design practices in the §6217 Guidance appear to be appropriate for the Virgin Islands, the territory may find that alternative practices will be more effective in controlling NPS pollution.

1. There are a number of practices in the Guidance to achieve adequate flushing. One practice is to site and design marinas such that the bottom of the marina and the entrance channel are not deeper than the adjacent navigable waters, unless it can be demonstrated that the bottom will support a natural population of benthic organisms.

   Existing water depths necessarily affect the entire marina layout and design so bathymetric surveys should be conducted for a proposed basin and approach channel. Marina basin and channel depths should be designed to gradually increase toward open water to promote flushing. Otherwise, isolated deep holes where water can stagnate may be created.

2. A second practice is to design marinas with as few segments as possible to promote circulation within the basin. Flushing efficiency is inversely proportional to the number of segments. For example, a one-segment marina will not flush as well as a marina in open water, and a two-segment marina will not flush as well as a one-segment marina. The physical layout of a marina, as determined by the orientation of the marina toward the natural water flow, can also have a significant effect on the flushing capacity. Ideally, the distance between the exchange boundary and the innermost portion of the basin is minimized; otherwise, elongation increases circulation time.

There will be better dissolved oxygen (D.O.) conditions in marinas that avoid improper channel entrance designs, bends, and square corners. These areas tend to trap sediment and debris. If square corners are unavoidable, then access points should be provided to allow easy cleanout of accumulated debris.

3. <u>In poorly flushing waterbodies, consider design alternatives to enhance flushing: an open marina basin over a semi-enclosed design; wave attenuators over a fixed structure</u>. A marina at the head of an embayment will normally have poorer flushing than one located near the opening. Obviously, safety and vessel protection will weigh heavily in this sort of siting decision.

4. Another practice is <u>to design and locate entrance channels to promote flushing</u>. Entrance channel alignment should follow the natural channel alignment as closely as possible to promote flushing. Any bends that are necessary should be gradual. In the Virgin Islands where the tidal range is small, the marina entrance should be designed to be as wide as possible to promote flushing while still affording vessel protection. Entrance channels aligned parallel to the direction of the prevailing winds also promote circulation.

   If the entrance channel is perpendicular to the waterway, shoaling can be a problem in areas of significant sediment transport due to currents. Shoaling can require increased maintenance dredging of the channel and can lead to water quality problems by reducing circulation.

   The orientation and location of a solitary entrance can impact marina flushing rates. When a marina is square or rectangular, a single entrance at the center of the marina produces better flushing. If a marina is circular, an off-center entrance channel will promote better circulation.

5. <u>Establish two openings, where appropriate, at opposite ends of marina to promote flow-through currents</u>. In situations where both openings cannot be used for boat traffic, a smaller outlet can be opened solely to enhance flushing. In other situations, a buried pipeline has been used to promote flushing.

6. The last practice has to do with land use: <u>designate areas that are suitable and areas that are unsuitable for marina development</u>. Provide advance identification of waterbodies that do or do not experience adequate flushing. Several years ago, Puerto Rico completed a marina siting study for the northeast coast. It is now uses as a basis for marina permit decisions in the commonwealth.

B. Water Quality Assessment Management Measure

The second management measure is to **"[A]ssess water quality as part of marina siting and design."** This management measure does not require a study per se but rather an assessment of water quality.

Assessment of water quality may be used to determine whether a proposed marina design will result in poor water quality. This may entail:

(1) pre-development and/or post-development monitoring of a marina or ambient waters;

(2) numerical or physical modeling of flushing and water quality characteristics; or

(3) both.

Cost impacts may preclude a detailed water quality assessment for marinas with 10-49 slips. A pre-construction inspection and assessment can still be expected, however.

Historically, water quality assessments have focused on two parameters: DO and pathogen indicators. DO levels may be used as a surrogate variable for the general health of the aquatic ecosystem. Pathogen indicators are used as a surrogate variable for assessing risk to public health through ingestion of contaminated water and shellfish and through bathing. Water quality assessments can be used to ensure that water quality standards supporting a designated use are not exceeded.

North Carolina conducted a post-development marina study to characterize the water quality conditions of several marinas and to provide data that can be used to evaluate future marinas.

Providing water quality information is already required nationwide when dredging is involved. Dredging a marina site or entrance channel requires a River and Harbors Act section 10 permit from the U.S. Army Corps of Engineers. If there is discharge into U.S. waters after dredging, then a Clean Water Act section 404 permit is required. DPNR would issue a section 401 water quality certification before the Corps would issue a section 404 permit. Section 10 and section 404 both require a permit applicant to present to the Corps information necessary for a water quality assessment. An expert knowledgeable in water quality and hydrodynamics may assess potential impacts using available information and site inspection.

As part of the section 401 water quality certification process, DPNR requires information about water quality. The Department needs to look at this certification process to see if it adequately addresses nonpoint source impacts.

C. Habitat Assessment Management Measure

The third management measure is to **"[S]ite and design marinas to protect against adverse effects on shellfish resources, wetlands, submerged aquatic vegetation, or other important riparian and aquatic habitat areas as designated by local, state, or federal governments."**

Coastal marinas are often located in estuaries, one of the most diverse of all habitats. The Mangrove Lagoon on St. Thomas is a good example of this. Estuaries contain many plant and animal communities that are of economic, recreational, ecological, and aesthetic value. These communities are frequently sensitive to habitat alteration that can result from marina siting and design. Biological siting and design provisions for marinas are based on the premise that marinas should not destroy important aquatic habitat, should not diminish the harvestability of organisms in adjacent habitats, and should accommodate the same biological uses have been classified. Important types of habitat for an area, such as wetlands and coral reefs, are usually designated by local and federal agencies. In some situations, however, the locations of all important habitats are not known. Geographic information systems show promise as a method of conveying important habitat and other siting information to marina developers and environmental protection agencies.

Currently, DPNR requires a habitat assessment in the Environmental Assessment Report (EAR) that is submitted as part of a coastal zone management major permit application for a marina.

Some of the practices in the §6217 Guidance associated with habitat assessment are already followed in the Virgin Islands. The practices are as follows:

1. Conduct surveys to characterize the project site.

   Characterization of a proposed marina project site is the first step to determine compatibility. This would include evaluation of physical properties, water quality characteristics, and available habitat and seasonal use of the site by benthic species, macroinvertebrates, resident and transient fish, birds, endangered species, etc.

2. Redevelop coastal waterfront sites that have previously been disturbed; expand existing marinas or consider alternative sites to minimize potential environmental impacts.

   The Virgin Islands should use caution with this practice since many marinas here may have been designed at the maximum sustainable size in the first place. This is especially important in areas identified as Areas for Preservation and Restoration and Significant Natural Areas.

3. Employ rapid bioassessment techniques to assess impacts to biological resources.

   Rapid bioassessment uses biological criteria and is based on comparing the community assemblages of the potential development site to an undisturbed reference condition.

4. Assess historic habitat function (e.g., spawning area, nursing area, migration pathway) to minimize indirect impacts.

5. Minimize disturbance to indigenous vegetation in the riparian area.

   Riparian areas are the vegetated ecosystems along a waterbody. They are generally more productive habitat, in both diversity and biomass, than adjacent uplands. They serve an important nonpoint source pollution control function in the Virgin Islands: mangroves reduce sedimentation; salt ponds filter storm runoff prior to its entry into coastal waters. Disturbance should be minimized or disallowed altogether.

6. Finally, the territory could develop a marina siting policy to discourage development in areas containing important habitat as designated by territorial and federal agencies.

   This type of land use policy would be useful in such places as Salt River. It could be incorporated into the proposed comprehensive Land and Water Use Plan or APC/APR management plans.

D. Shoreline Stabilitization Management Measure

"Where shoreline erosion is a nonpoint pollution problem, shorelines should be stabilized. Vegetative methods are strongly preferred unless structural methods are more cost effective, considering the severity of wave and wind erosion, offshore bathymetry, and the potential adverse impact on other shorelines and offshore areas."

Shoreline erosion is not always a NPS pollution problem, but where it is, the shoreline should be stabilized. (It is usually in the best interest of the marina operator to minimize erosion anyway to reduce sedimentation and the frequency of dredging). The Virgin Islands is fortunate to have red mangroves which are relatively easy to plant under the right circumstances and offer excellent shoreline protection. Another advantage of this vegetative protection is its affordability. But mangrove effectiveness varies with the amount of wave reduction provided by the physiography and offshore bathymetry of the site.

In some cases, structural techniques such as gabions, riprap, and sloping revetments can dissipate wave energy that can cause erosion. Bulkheads, jetties, and breakwaters are other structural methods to stabilize shorelines and navigation channels, but they may also cause scouring in front of the structure and increase erosion of the adjacent shoreline.

E. Storm Water Runoff Management Measure

"Implement effective runoff control strategies which include the use of pollution prevention activities and the proper design of hull maintenance areas.

"Reduce the average annual loadings of total suspended solids (TSS) in runoff from hull maintenance areas by 80 percent. For the purposes of this measure, an 80 percent reduction of TSS is to be determined on an average annual basis."

This management measure is intended to be applied by states and territories to new and expanding marinas, and to existing marinas for at least the hull maintenance areas. If boat bottom scraping, sanding, and/or painting is done in areas other than those designated as hull maintenance areas, the management measure applies to those areas as well. This measure is not applicable to runoff that enters the marina property from upland sources.

The principal pollutants in runoff from marina parking areas and hull maintenance areas are suspended solids and organics (predominantly oil and grease). Toxic metals from boat hull scraping and sanding are part of, or tend to become associated with, the suspended solids. The proper design and operation of the marina hull maintenance areas is a significant way to prevent the entry of toxic pollutants from marina property into surface waters. Recommended design features include the designation of discrete impervious areas (e.g., cement areas) for hull maintenance activities; the use of roofed areas that prevent rain from contacting pollutants; and the creation of diversions and drainage of off-site runoff away from the hull maintenance areas for separate treatment. Source controls that collect pollutants and thus keep them out of runoff include the use of sanders with vacuum attachments, the use of large vacuums for collecting debris from the ground, and the use of tarps under boats that are being sanded or painted.

The perviousness of non-hull maintenance areas should be maximized to reduce the quantity of runoff. Maximizing perviousness can be accomplished by placing filter strips around parking areas. Swales are strongly recommended for the conveyance of storm water instead of drains and pipes because of their infiltration and filtering characteristics.

Suspended solids are solid materials that remain suspended in the water column. The annual TSS loadings can be calculated by adding together the TSS loadings that can be expected to be generated during an average 1-year period from precipitation events less than or equal to 2-year/24-hour storm. The 80 percent standard can be achieved, by reducing over the course of year, 80 percent of these loadings. EPA recognizes that 80 percent cannot be achieved for each storm event and understands that TSS removal efficiency will fluctuate above and below 80 percent for individual storms. The 80 percent removal of TSS is applicable to the hull maintenance area only. Although pollutants in runoff from the remaining marina property are to be considered in implementing effective runoff pollution prevention and control strategies for all marinas, existing marinas may be unable to economically treat storm water runoff.

These are a number of techniques for controlling maintenance area runoff. They include (1) filtration/infiltration, (2) retention, detention, and (3) physical separation of pollutants. Because these were covered in the storm water runoff session, I will not get into them here. Please refer to the §6217 Guidance for additional details.

Because of the steady breezes, heavy downpours, soil types, and limited land areas suitable for haulout facilities in the Virgin Islands, source controls at marinas such as sanders with vacuum attachments may be more appropriate for both health and NPS pollution control purposes than filters, strips, wet ponds, infiltration basins and trenches, or grassed swales.

F. Fueling Station Design Management Measure

Another sound objective in designing a marina is to **"[D]esign fueling stations to allow for ease in cleanup of spills."** This is required under the §6217 program for new and expanding marinas where a fueling station is being added or moved, but, for the most part, it is already required in the Virgin Islands under other territorial and federal authorities.

The possibility of spills during fueling operations always exists. Since most petroleum-based fuels float on the water's surface, this allows for their capture if containment equipment is uses in a timely fashion. The following practices can be applied successfully to achieve this management measure.

1. <u>Locate and design fueling stations so that spills can be contained in a limited area.</u>

   Fuel station location and design should be such that booms can be deployed to surround a spill.

2. <u>Design a Spill Contingency Plan.</u>

   A plan that meets local and federal requirements is probably already required in the Virgin Islands for fuel storage and dispensation areas. Marina personnel should be properly trained in spill containment and control procedures.

3. <u>Design fueling stations with spill containment equipment.</u>

   Appropriate equipment should be stored in a clearly marked, easily accessible cabinet or locker.

G. Sewage Facility Management Measure

<u>"Install pumpout, dump station, and restroom facilities where needed at new and expanding marinas to reduce the release of sewage to surface waters. Design these facilities to allow ease of access and post signage to promote use by the boating public."</u>

This management measure applies to new and expanding marinas in areas where adequate marine sewage collection facilities do not exist. Pumpout stations are for vessels equipped with marine sanitation devices (MSDs) and dump stations are for vessels with portable toilets. A marina should choose a pumpout facility and/or dump station based on the types of vessels it services. In the Virgin Islands, there currently are not any pumpout stations in operation.

There are (1) fixed point systems, (2) portable/mobile systems, and (3) dedicated slipside systems available. Fixed point collection systems are generally located on the end of pier, often near the fueling station so that pumpout and fueling operations can be combined. Pumps or vacuum systems remove sewage from the vessels to an approved disposal facility.

A portable unit includes a pump and a small storage tank. In many cases, these units are considered the most logistically feasible, convenient, accessible, and therefore, economically affordable method for a marina. In some locations in the

U.S., a radio dispatched pumpout vessel will service vessels in a marina or mooring field.

Dedicated slipside systems provide continuous wastewater collection at a marina slip for vessels equipped with MSDs. These are appropriate for liveaboard vessels in a marina.

Adequate signage should be provided to advertise pumpout service availability and public restroom facilities.

H. Other Design Considerations

During the design phase of a marina, attention to the environmental concerns of marina operation will significantly reduce the potential for NPS pollution from day-to-day activities. Siting and design of trash facilities, waste oil and other liquid disposal sites, and fish cleaning and disposal sites should be key considerations in marina layouts. Adequate and well-marked facilities in appropriate, protected locations within the marina can minimize the entry of pollutants into marina waters.

In addition to proper marina siting and design considerations, public education for boaters and marina operators can go a long way toward preventing NPS pollution.

Conclusion

In conclusion, many factors influence the long-term impact that a marina or boatyard will have on water quality and habitat in the immediate vicinity of the marina and the adjacent waterway. Initial marina site selection is the most important factor. A site with favorable hydrographic characteristics that requires the least amount of modification can reduce potential NPS impacts. Whether a marina is open or semi-enclosed and its configuration will affect its circulation and flushing characteristics. The final design is usually a compromise that should produce a favorable combination of marina capacity, services, and access while minimizing environmental impacts, dredging requirements, protective structures, and other site development costs.

MARINA OPERATION AND MAINTENANCE/OUR FRAGILE ENVIRONMENT

Kim E. Lindlau

American Yacht Harbor, Red Hook, St. Thomas, USVI 00802

We must protect our natural resources through awareness, education and communication.

The marine industry plays a very large part of the overall economy of our islands. Vessels travel great distances to enjoy and share our beautiful pristine waters. The United State Virgin Islands have much to offer the boating industry, we have location, climate, and almost constant trade winds. By the same token the boats are the life sustaining force for many marine related businesses. Over the past few years we have lost numerous vessels to other islands due to incentives and lower operational costs. Hurricane Hugo also lowered the overall size of the fleet. Both losses have affected the marine industry which directly affects the Islands economy. Not only should we be aware of the positive impact these vessels have on our islands, we should also be aware of the environmental mishaps that can occur if proper education and communication is not available.

My office operates with an open door policy. Should a problem occur on land side or water side, chances are I've had dealings with it in the past. Response time is very important as part of the final result. Therefore as soon as a manager is made aware, the sooner actions can be taken to correct it. Again Communicate. I believe this policy works for any business.

The ownership, management and staff of American Yacht Harbor are environmentally aware of their surroundings. The redevelopment which is in progress has taken into account not only the federal and local rules and regulations which govern us but future rules and regulations. The fuel system was designed to meet all EPA requirements. We have fiberglass double walled tanks and lines. We also use three different types of leak detection.

1. Leak detection at the tanks.
2. Accounting fuel inventory.
3. DPNR Petroleum Inventory Control Form.

Petroleum products are very damaging to our environment. The waste oil problem has been affecting these islands for many years. However, there has been a waste oil committee formed to find a long term solution to this problem. The membership includes very dedicated people from the government and private sector.

For years waste oil has been disposed of in dumpsters, poured in guts or just poured along the side of the road. Probably sooner than later this oil will reach our coastal waters, pollute our wells and contaminate our water table. Storm run off and saturation will speed this process along. When an agreeable solution is found, a massive educational program will follow to stop this type of pollution. At this time double containment and very strict maintenance programs are recommended, not only for the marine environment but for all of us.

American Yacht Harbor has had double containment for a number of years and the location is visited on a regular basis by a staff member. It is very important to keep the surrounding area clean and clear of small, full containers of oil. We have seen everything from open coffee cans to 5 gallon containers with the lids full of oil, rainfall then complicates the matter by spreading it into the containment area on the ground. We have a oil boom and until recently only absorbent pads (which unfortunately absorb more water than contaminate). We have now added to our inventory a product called Spil CAT.

Spil CAT:

1. Encapsulates oily liquids on contact and prevents them from causing further damage to the environment.
2. Floats and will remain floating after application on spills.
3. Is lightweight
4. Absorbs sixty times its weight.
5. Will not absorb water.
6. Is non-toxic.
7. Non-flammable.
8. Non-hazardous.
9. Non-corrosive.
10. Has a long shelf life.

It appears this product is environmentally friendly and can reduce costs in oil cleanup plus help protect our ecosystem.

In closing, it's our environment, let's take care of it to the best of our ability. Remember the agencies here today are here to help us. They don't expect anyone to know all the answers but they do hope we know the proper questions to ask.

CONSEQUENCES OF DREDGING COASTAL HABITATS IN THE WESTERN PACIFIC OCEAN AND IN WATERS AROUND ST THOMAS / ST JOHN, U.S. VIRGIN ISLANDS

N.J. Quinn[1] and B.L. Kojis[2]

[1]Eastern Caribbean Center, University of the Virgin Islands, No. 2 John Brewers Bay, St. Thomas, United States Virgin Islands 00802. [2]Department of Planning and Natural Resources, Government of the Virgin Islands of the United States, St. Thomas, United States Virgin Islands 00802.

INTRODUCTION

Many dredging projects are related to people's desire to travel, engage in trade, fill or enhance shorelines, or, particularly in the Pacific, establish military bases. On small islands airports are usually located in the coastal zone and often substantial lands have to be filled and causeways constructed to provide land for runways and terminals. Docks and ports must be located at the shoreline and frequently require shoreline alteration and sea bed modification to accommodate vessels. Dredge spoil has been used to fill submerged lands, to provide cover for garbage dumps, and to enhance beaches. U.S. expansionist interests during the Cold War resulted in dozens of remote military bases being constructed on uninhabited islands in the Pacific Ocean. Many of these islands required major dredge and fill operations to accommodate military activity.

PHYSICAL CONSEQUENCES

The following lists the probable effects of mechanical excavation and dredging:

1) the bottom is physically disturbed and habitat for bottom dwelling organisms removed,
2) sediment is deposited on the sea bottom,
3) sediment is suspended in the water column,
4) toxic substances are reintroduced into water column,
5) light penetration is reduced,
6) the oxygen content of the water is reduced,
7) turbidity increases,
8) circulation patterns change,
9) dissolved oxygen levels are reduced,
10) nutrient levels increase, and

11) indirect damage is caused by anchors, moorings and slurry pipes.

The most widespread and visible consequence of dredging and excavation is the generation of suspended sediments and turbidity. This paper will focus on the ecological aspects that are the result of the physical consequences of dredging.

ECOLOGICAL CONSEQUENCES

An unavoidable impact of any dredging operation is the direct elimination of the bottom habitat in the dredged area and loss of associated species. The accumulation of sediment on the bottom in adjacent areas can also have a significant adverse effect on the animals and plants on the bottom.

Depending upon the extent of the alteration caused by dredging, recolonization may eventually be possible on many dredged surfaces. However, it generally takes a long time, perhaps several decades, for the fauna and flora to return to its original state. Harbor bottom environments tend to accumulate fine sediments and are most often colonized by soft-bottom or sand-dwelling communities. If the orginal harbor bottom was a seagrass community, it may be many years before this type of community return. Dredged hard surfaces that are not deep (greater than 30 ft depth) and exposed to waves and currents (such as quarry holes on outer reef flats in the Pacific) can be extensively recolonized by reef life within a decade following dredging (Maragos, 1987).

The recolonization of hard substrate in the Caribbean is poorly known and needs additional study. Currently we are investigating colonization of reefs in three sites around St. Thomas, but results are not expected for some time.

Corals and many other reef organisms are adapted to clear waters and are particularly susceptible to turbidity caused by dredge and fill operations. Knowledge of currents in the construction area allows prediction of direction and persistence of turbidity plumes, thereby facilitating assessment of potential impacts of dredging surrounding marine communities.

Studies by Kojis and Quinn (1984) found that the ability of corals to reproduce was affected by the levels of sedimentation at various sites. Corals living in regions of high turbidity released fewer larvae and only grew in shallow water. A smaller zone of living reef reduces the area which associated reef fish may live and in effect reduces the productivity of an area. Over a prolonged period of time high sediment loads result in lower diversity, percent cover, and growth rates of coral species, smaller colony sizes, an

upward shift in depth zonation, and a predominance of resistant growth forms or species (Rogers, 1990).

There have been few studies that address the effects of suspended sediments on growth and mortality of individual coral species. Field studies have demonstrated that growth rates of the Caribbean mountainous star coral (<u>Montastrea annularis</u>) diminish as sediment loads increase (Dodge, <u>et al</u>., 1974; Hubbard, <u>et al</u>., 1987). However, workers in the Pacific have found that there was little or no evidence of decreased growth rate for surviving colonies of <u>Porites lutea</u> (a species often found in turbid waters) even in areas where high mortality of other coral species has been attributed to the effects of sedimentation (Hudson, <u>et al</u>., 1992). Laboratory experiments evaluated the resistance of seven coral species found in the subtropical waters off Tampa Bay to 49 to 199 mg per liter of suspended natural marine sediments for 10 days. Although growth rates decreased, all corals survived (Rice and Hunter, 1992).

Local currents and exposure to wave action also play a role in recruitment and survival rates of marine organisms. Variation in these rates determine the distribution and zonation of corals and other marine life. Consequently, dredging and the resultant physical modification of topographic features that may alter current regimes and exposure to wave action also can have profound effects on reef community structure in a surrounding area.

Indirect impacts of dredging include anchoring operations for barges, ships, and pipelines. Placement and dragging of anchors and pipes over sensitive ecosystems can damage coral, and to a lesser extent, plant communities.

ECOLOGICAL CONSEQUENCES: DOCUMENTED EXAMPLES

A. <u>Pacific Ocean</u>

1. Federated States of Micronesia

At Okat Reef, Kosrae, Federated States of Micronesia (Fig. 1), the rate of slurry discharged into a retention basin exceeded the basin's capacity, causing slurry to overflow the walls, spill out over 25 acres of seagrass and coral habitat, and completely bury it under 0.8 to 1.5 feet of fine slurry muds. The impact could have been prevented by a reduced rate of slurry discharge, but the construction contractor had a schedule to meet and was unwilling to slow operations (Maragos, 1984). Dredging further destroyed reef and sea grass meadows and greatly altered circulation in the harbor. The stronger water currents were implicated in shoreline erosion near the airfield and Tafunsak Village. The impacted reef was once Kosrae's most important fishing ground. Fish yields at Okat reef have declined to half of preconstruction levels (Maragos, 1984).

2. Kaneohe Bay, Hawaii

Military dredge and fill operations between 1938 and 1950 increased circulation in the north part of Kaneohe Bay, Oahu, Hawaii, but reduced circulation in the south part (Fig. 2). Additonally, the southern part of the bay was impacted from sewage outfalls constructed in 1950. By 1970, only northern bay reefs were recovering while central and southern bay reefs declined because of sewage pollution.

The sewer outfalls were removed from the bay during the years 1977-1978, allowing for coral recovery in the central and southern bay. The recolonization of corals on dredged surfaces was accelerated after removal of sewage outfalls in the nearby lagoon and relocated to outside the lagoon. The discharge of primary treated sewage does not appear to have adversely affected the reefs because of it us discharged at a depth of 35 m and there is excellent mixing and flushing at the new site (Maragos, et al., 1985).

3. Taongi Atoll

Many enclosed Pacific atolls have elevated lagoon water levels because of wave action pumping water over windward reefs and the lack of large, deep channels to drain the excess water. The reefs grow above normal ocean sea level because of constant water flow and the resultant elevated water level. Dredging a deep channel through such an atoll reef causes waters to drain more quickly, lowering the lagoon water level and killing emergent reefs. This occurred at Taongi Atoll (Fig. 3) (Maragos, 1989).

4. Palmrya Atoll, U.S. Line Islands

Construction of road causeways around the East Lagoon at Palmyra Atoll, U.S. Line Islands by the U.S. Navy completely blocked circulation, causing collapse of coral reef communities (Fig. 4). Dredging of a channel through the western reef and between the central and east lagoons destroyed reefs and altered water circulation. Sediments drifting west from the dredge and fill areas damaged reef communities off the western end of the atoll. By 1979, some of the northern

causeways had breached restoring some exchange between the east lagoon and the Pacific Ocean. Observations in 1987 found only partial recovery of the reefs from military construction (Maragos, 1979; 1987).

B. <u>Virgin Islands</u>

Numerous dredging activities have occurred in the Virgin Islands. These activities range from small localized activities to maintain channel depth to the larger dredging projects to maintain harbors and fill wetlands. Among the major dredging projects in the U.S. Virgin Islands are two that exemplify some of the changes and problems created by dredging: Great Cruz Bay, St. John and at Water Bay, St. Thomas.

1. Great Cruz Bay

The dominant biotic feature of Great Cruz Bay is an algal sea grass meadow characterized by Manatee and Turtle grass interspersed with worm hummocks and green algae such as *Penicillus*, *Udotea* and *Halimeda*. Queen conch and the long-spined black sea urchin were once common, and healthy fringing coral reefs were present along the northwestern and southwestern shore (vanEepoel & Grigg, 1970).

In 1968, dredging of 186,000 cu. yd. was permitted in the bay to a depth of 15 ft within 300 ft of the shore (Fig. 5). The area dredged was a rich seagrass and algal meadow. The bulk of the dredge spoil was used to fill in wetlands while the rest was used for construction in the Hyatt Regency Hotel. Dredging occurred at the same site in 1985.

Although the Corps of Engineers 1968 permit required compliance with federal and local regulations regarding water pollution, no attempt was made to minimize the quantity of fine material in suspension in the water. However, despite this, the predicted destruction of the benthic biota outside the dredged area (vanEepoel and Grigg, 1970) did not occur. In 1985, the area was dredged again. Eight years later in August 1993, we found the dredge site characterized by soft sediments inhabited by burrowing organisms, little algae, and no sea grass.

The water clarity, measured using a Secchi disc, in the dredged area was 1.6 ft in 1970 (vanEepoel and Grigg, 1970). When we sampled water clarity on a calm day in August 1993, the Secchi disc reading was 4.5 ft. This is still poor and unattractive compared to the clearer water over the sea grass meadows near the entrance of the bay. In both 1970 and in August 1993, the sea grass meadows near the entrance of the bay could be clearly seen (>20 ft deep).

2. Water Bay

Between 1961 and 1970, a ten year period, approximately 750,000 cubic yards of sand were dredged from Water Bay (Fig. 6) for various land fill, construction, and beach nourishment projects. This dredging operation removed the bottom cover of sea grasses and algae. The result was that fine sand and silt particles were no longer trapped and turbidity remained "undesirable" (Grigg and vanEepoel, 1970).

During the ten year period that dredging occurred, the living animals on the fringing reef on the east side of the bay gradually died. These changes were called "... a major ecological disaster for the sub-littoral flora and sessile fauna" (vanEepoel, 1969). While not on the order of a Gulf of Valdez oil spill, the gradual destruction of habitat diminished the productivity and natural beauty of the territory's coastal waters.

Dredging of Water Bay not only destroyed habitats, it also was responsible for loss of sand from Sugar Bay Beach. Originally it was believed that the presence of the dredge holes in Water Bay promoted "slumping" of the Sugar Bay beach sand into the holes (Brody cited in VIMA, 1992). However, various reports describe the stockpiling of sand on the eastern end of Sugar Beach which would have required the slurry pipes to traverse the live reef and this would have damaged the reef. A recent theory is that as a result of the damage to the reef, Sugar Beach was provided less wave protection and severe erosion occurred (VIMA, 1992). Specifically, as a result of physical damage to coral (primarily elkhorn corals) caused by the pipes, the height of the reef surface was lowered, increasing wave energy which rapidly eroded the beach (VIMA, 1992). The clean, carbonate sandy beach became dominated by 10-20 cm cobbles. The beach in its present condition does not provide easy access to the sea for bathers and diminishes the appeal of the new Sugar Bay Plantation Hotel.

In 1992, permission was sought to replenish the sand on the beach using 4,000 cu yd of sand purchased from off island and to place boulders on top of the reef to simulate the protection previously naturally provided by the reef. The irony is that one of the original uses of the dredge spoil was to enhance beaches in the bay.

Monday morning quarterbacking is fun unless you are the one who must pay for someone else's mistakes.

PATHOLOGICAL EFFECTS ON HUMANS

Dredging, filling, and other physical changes to habitats in the tropics have been implicated in the increased incidence and outbreaks of ciguatera fish poisoning. The poisoning is caused by a toxic dinoflagellate, Gambierdiscus toxicus (single celled plant), growing on macroscopic algae, which are consumed by herbivorous fish. The herbivores are eaten by carnivorous fish and the toxin passed up the food chain. Although mildly toxic to fish, ciguatera is much more toxic to mammals, including humans. There is considerable circumstantial evidence for a relationship between ciguatera and construction activities. Ciguatera was absent on some Pacific atolls before construction, but outbreaks occurred on atolls such as Palmyra, Johnston and Bikini during and after construction.

RECOMMENDATIONS

Recommendations for alleviating impacts of dredging:

1) Choose an appropriate site. Locate a site with natural conditions that would minimize impacts. Avoid particularly valuable or sensitive areas.

2) Test dredge material to determine its composition and if it is toxic.

3) Select best available appropriate technology (BAAT). The selection of BAAT will help minimize turbidity and sedimentation during both the dredge operation and spoil dumping. Dredge spoils can often be collected in cascaded settling ponds and, if not toxic, used for alternative purposes such as fill or other construction related purpose.

If the dredge spoil is toxic, contact the Department of Planning and Natural Resources, Division of Environmental Protection for information on suitable disposal methods.

Physical barriers such as silt screens surrounding the dredging operation and a combination of silt screens and earthen berms on the spoil site can be effective in reducing turbidity. Silt screens are curtains of plastic, fiberglass, or other fabric that in the water are hung from the surface using a system of floats and anchors; normally, silt screens are effective where wave action is low and water currents are 2 ft/sec or less.

3) Consider the restoration potential of the site after dredging and restore the site if possible.

4) Beware of indirect impacts of dredging such as anchoring operations for barges, ships, and pipelines. Avoid placing anchors in and dragging them over sensitive ecosystems such as coral reefs and algal / sea grass meadows.

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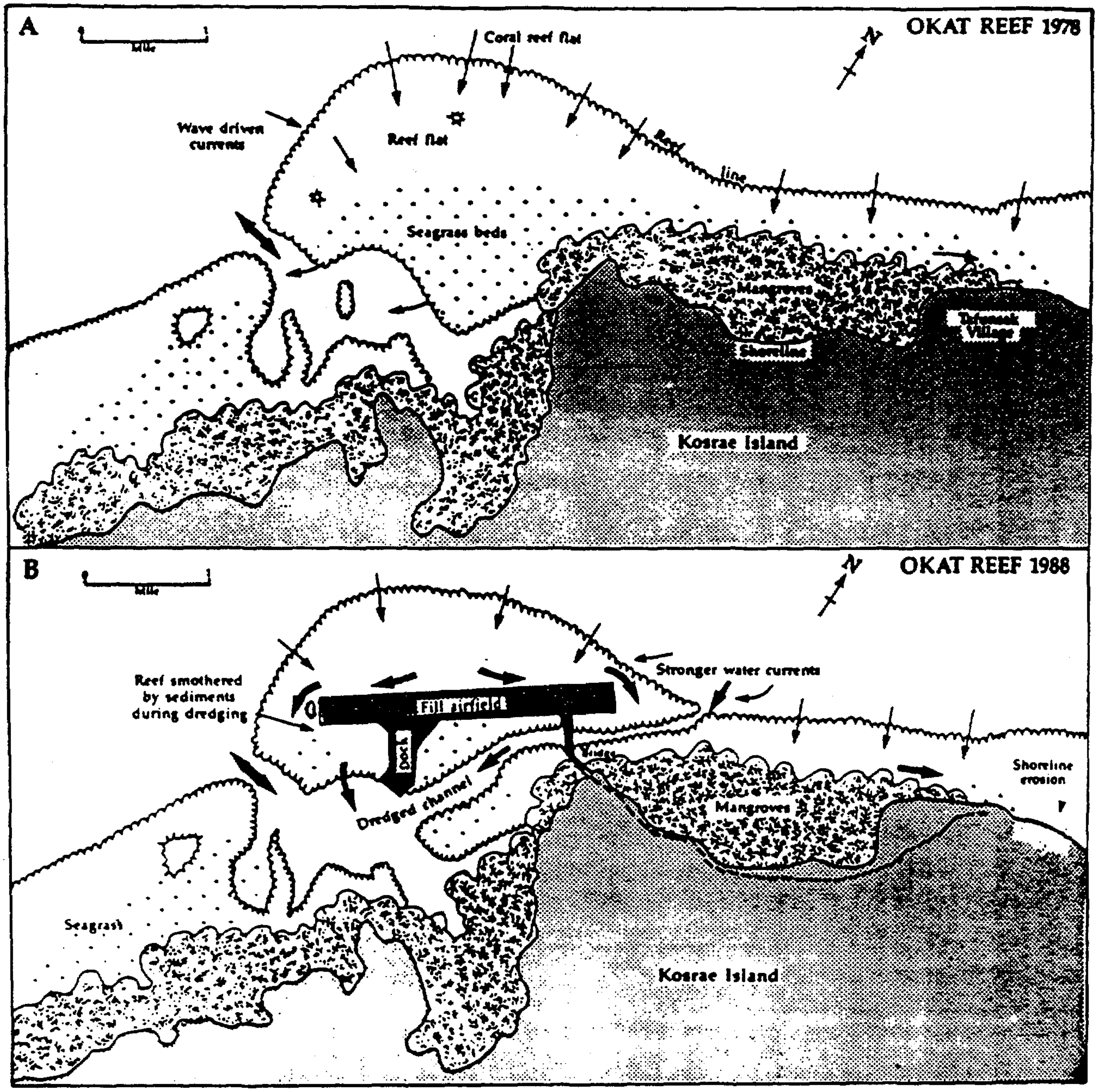


Figure 1. Adverse effects of dredge and fill for reef flat runway and dock construction at Okat, Harbor, Kosrae Island, Federated States of Micronesia (adapted from U.S. Army Corps of Engineers 1989).

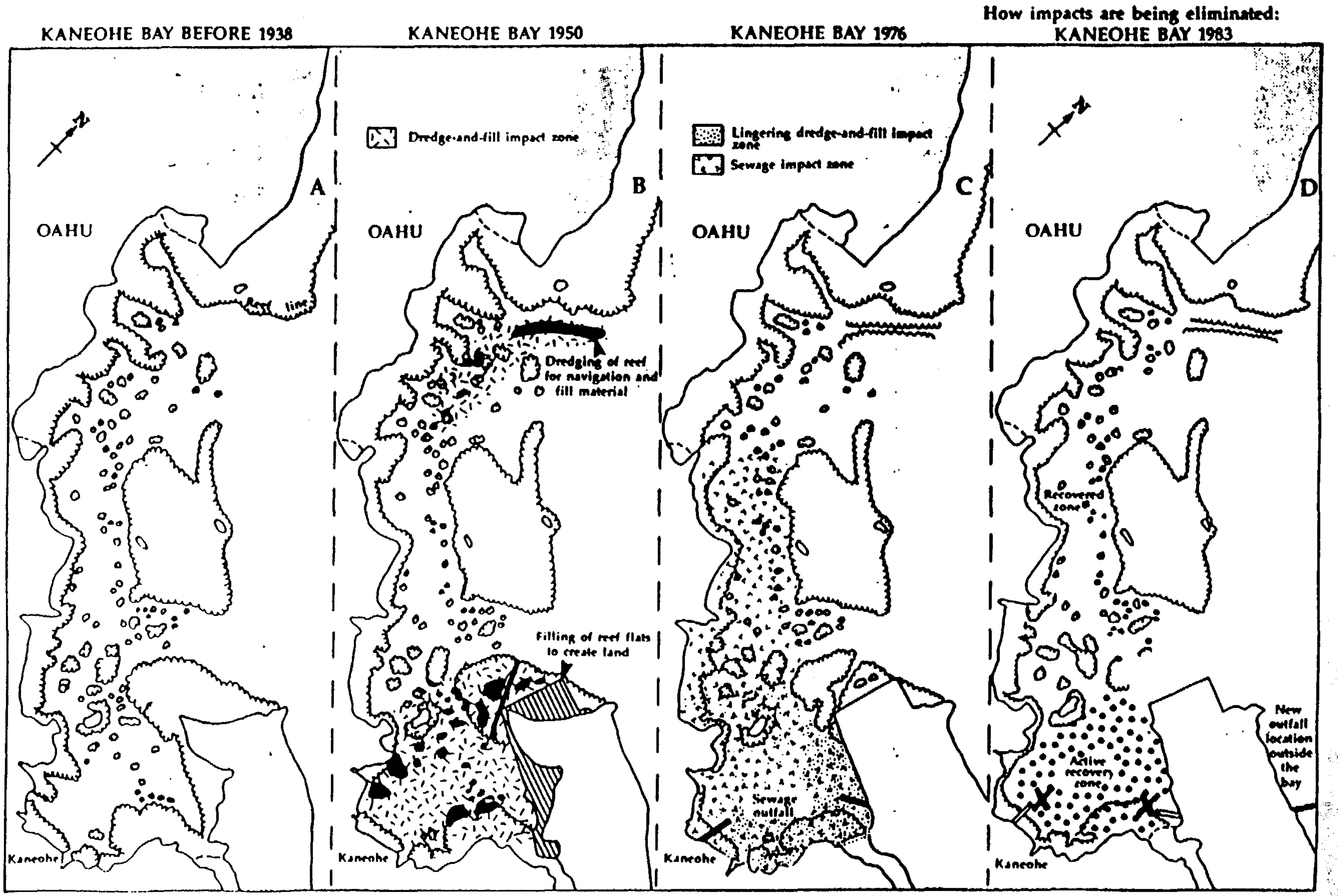


Figure 2. Adverse effects of dredging, filling and sewage discharge in Kaneohe Bay, Oahu, Hawaii (after Maragos <u>et al</u>., 1985).

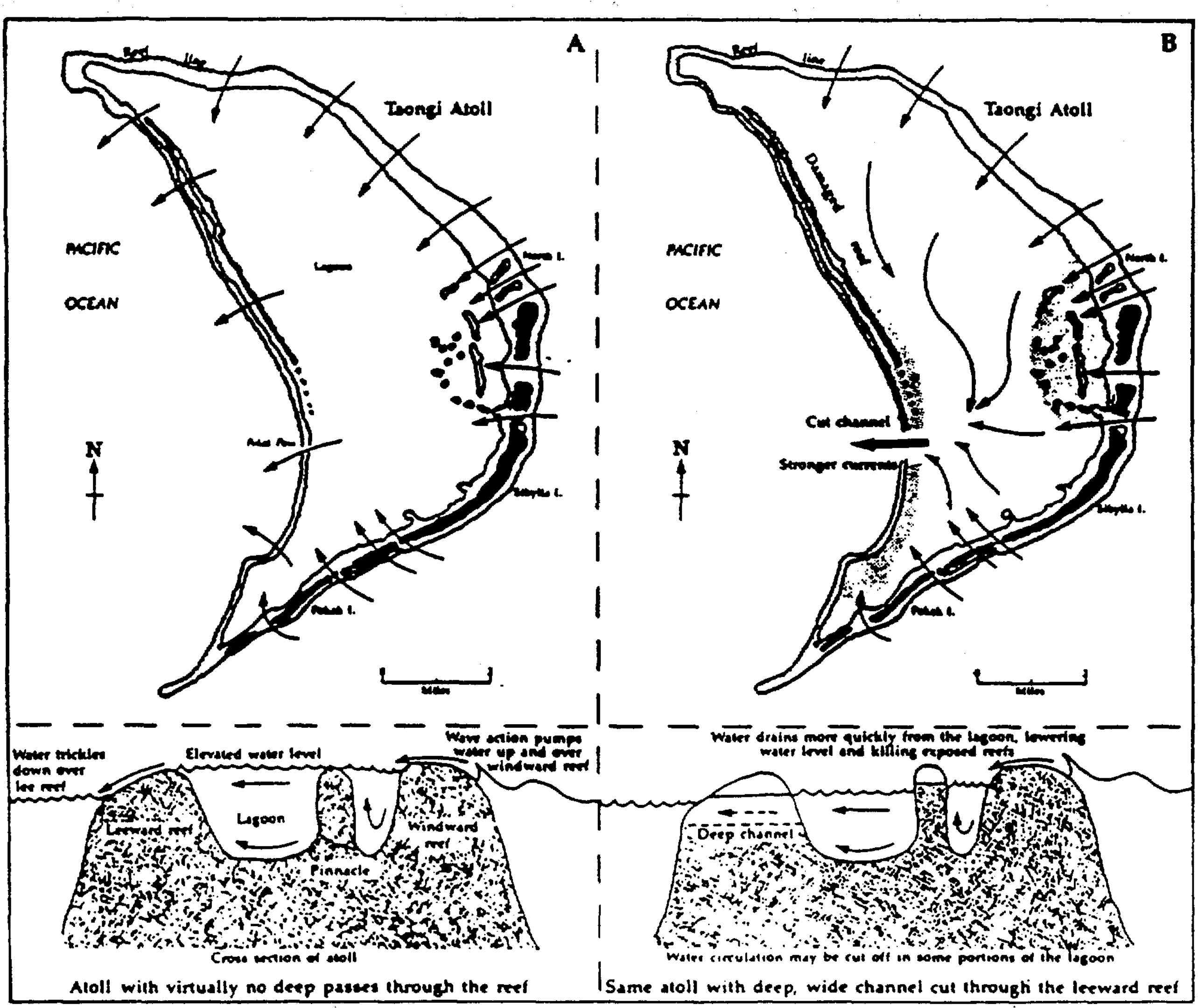


Figure 3. Adverse effects of dredging channels through semi-enclosed lagoons (after Maragos, 1989).

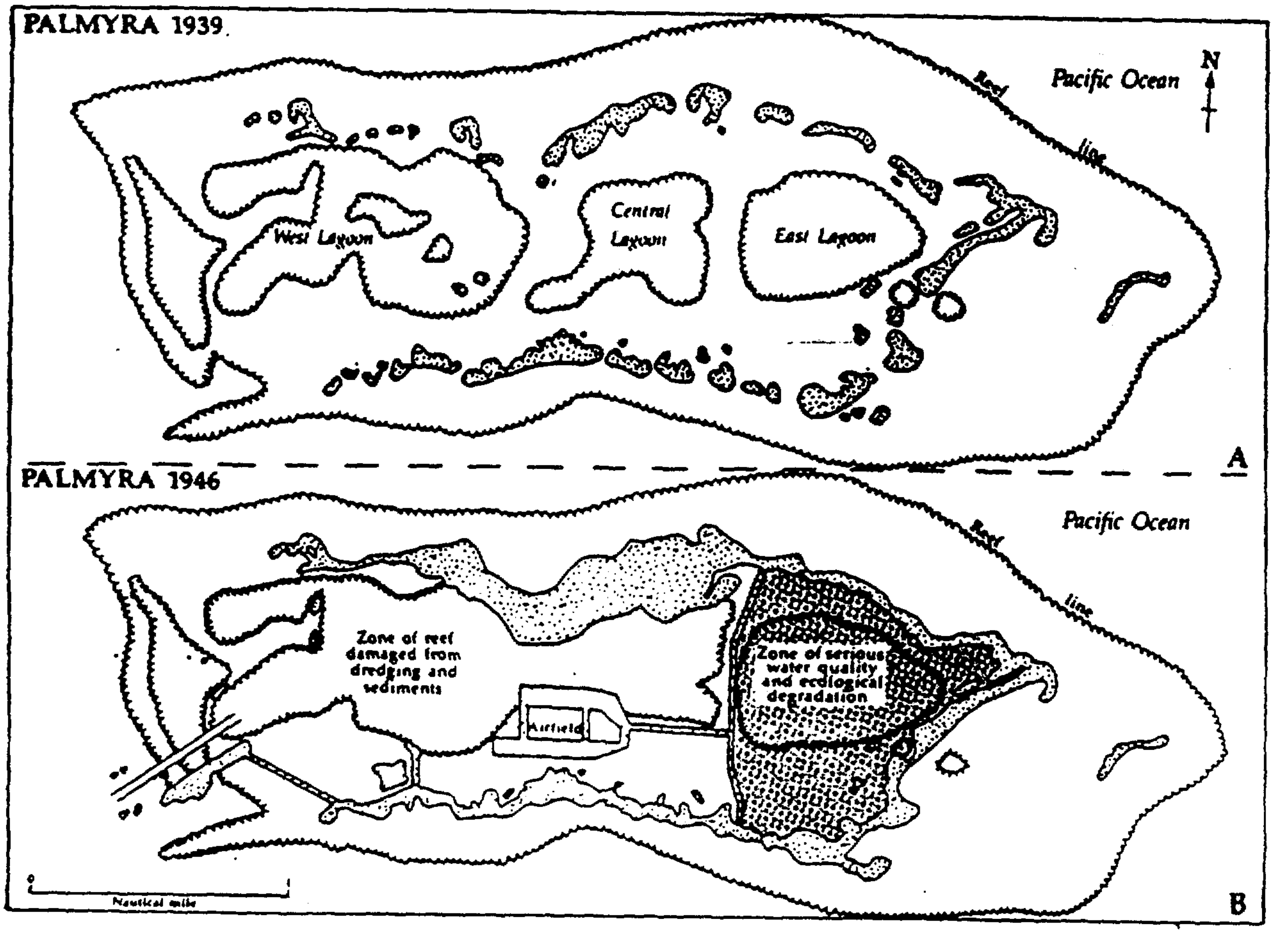


Figure 4. Adverse effects of dredge and fill operations at Palmyra Atoll, U.S. Line Islands (after Maragos, 1987).

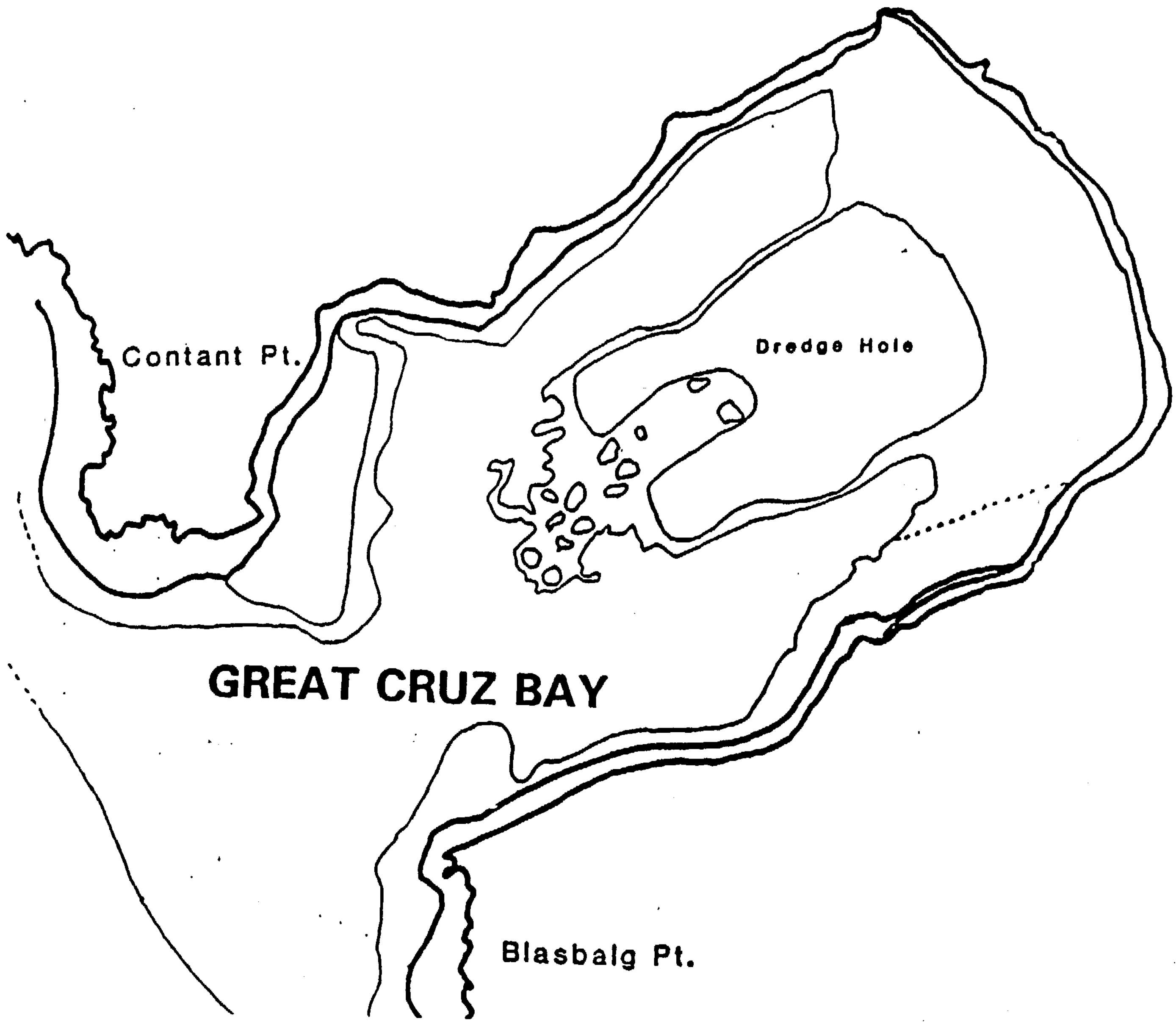


Figure 5. Location of 1960's dredge site in Cruz Bay, St. John, U.S. Virgin Islands

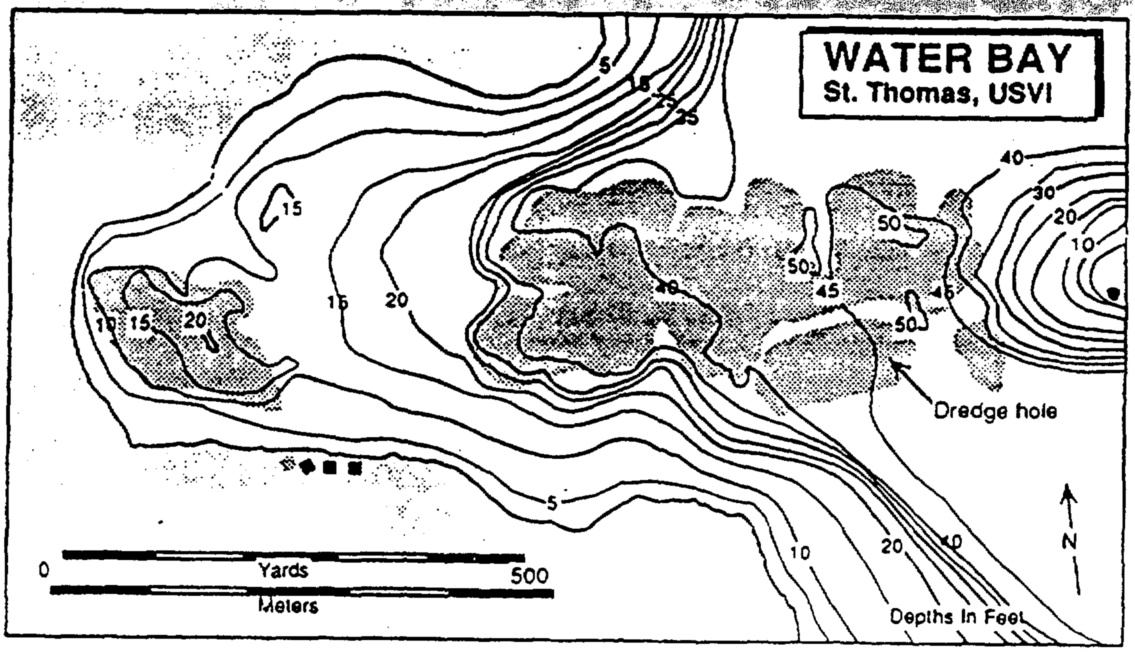


Figure 6. Location of dredge site in Water Bay, St. Thomas, U.S. Virgin Islands (after VIMA, 1992).

HOW TO PREVENT OR MINIMIZE BEACH EROSION

Dennis K. Hubbard
V.I. Marine Advisors, 5046 Cotton Valley, St. Croix, USVI 00820

Introduction

Beach erosion has become an increasingly prevalent problem in the territory, primarily for two reasons. First, sea level continues to rise, as it has for the past 18,000 years. Global warming tied to the increased introduction of carbon dioxide and other "greenhouse gasses" into the atmosphere may result in dramatic acceleration of sea-level rise over the coming decades. However, this remains largely a natural phenomenon over which we have little direct control. Our best response to this is awareness and the careful siting of development in areas that will be least affected. The other, and more controllable, factor in increased beach erosion is the accelerating pattern of development and the mistakes that are too often associated with it. These are the most-easily remedied and are the focus of the discussion below.

What Causes Beach Erosion

Most-simply stated, erosion occurs when more material leaves an area than is being delivered to it. While seemingly a simple concept, ignoring this immutable law of nature lies at the heart of most beach-erosion problems that we face today. The key is, therefore, to recognize the factors that result in this imbalance and to suggest ways to avoid or remedy them.

Natural beach erosion is generally occurring to some degree throughout the territory. This is related in part to the gradual rise in sea level mentioned above and in part to the natural tendency for waves to break down the materials that comprise our shores and to move them offshore. Beyond this, most of the problems that we have seen are related to somehow interrupting a natural pattern that has in the past resulted in a near balance between sediment coming in and sediment going out. This usually takes one of two forms. First, some sort of physical barrier can be placed in the nearshore system that prevents sand from moving along the beach. The simplest example is a groin (Fig. 1), a linear structure erected perpendicular to the shoreline. Because waves approach at an angle, sediment is moved dominantly in one direction along the shore. In the Virgin Islands, this is generally toward the west as a result of the prevailing Trade Winds. A groin placed across a beach will trap sand along its eastern side because the sediment is

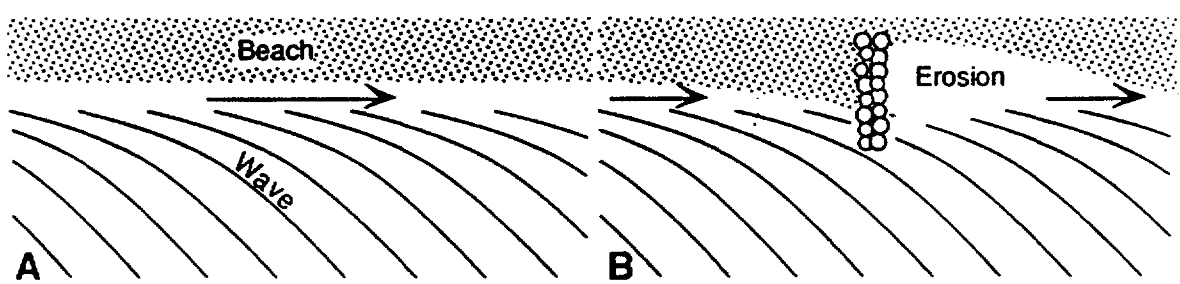


Figure 1. Alongshore sediment transport without (A) and with (B) a beach groin present. Once the rock structure is in place, sediment moving from left to right is trapped by the groin. As a result, the beach on the left accretes and the one to the right erodes. This is in contrast to the uninterrupted transport without any structure.

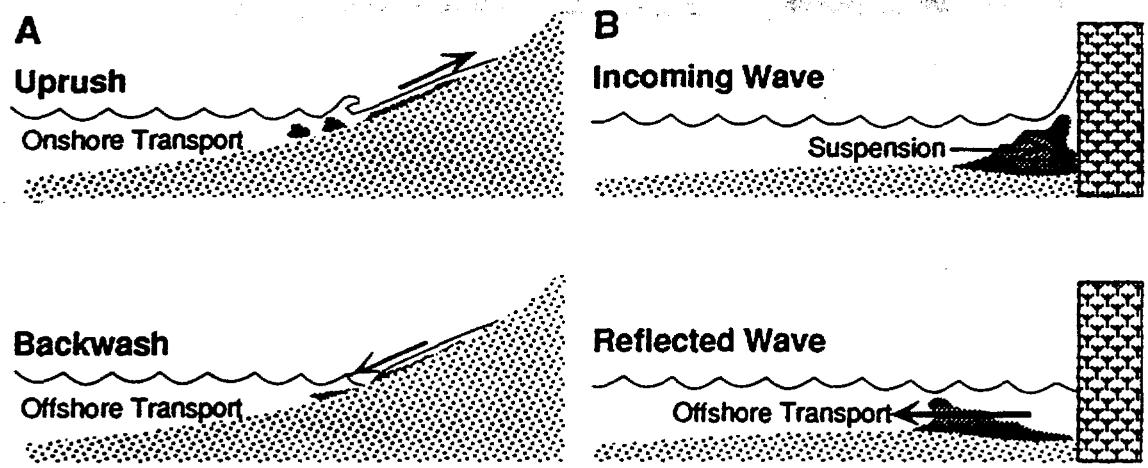


Figure 2. Wave-induced sediment transport on a natural beach (A) and against a seawall (B). On the sloping beach, the uprush and backwash have roughly equal transport potential. As a result, the beach remains stable until a storm passes. In contrast, waves reflecting off the seawall stir up sediment on the way in, leaving it in suspension for the reflected wave to move it offshore. This process continues until the nearshore zone fronting the wall is scoured to a depth where the waves can no longer effectively suspend the resident sediment.

coming in naturally from the east, but cannot get past the groin and move out to the west. On the other side of the structure, sand is being moved away to the west, but is not being replaced. The result is erosion.

The second common cause of beach erosion involves modifying natural processes in a manner that favors net sediment export. One of the most commonly used coastal-protection structures is the seawall. This structure armors a stretch of eroding shoreline, creating security for the properties immediately behind it. The problems with these ubiquitous features are many, however. The most problematic is scour. When waves encounter a vertical or steeply sloping surface, they reflect seaward. The reflected wave carries with it large quantities of sediment, resulting in erosion along the base and ends of the wall, sometimes undercutting the structure to the point of collapse.

To understand the nature of this complex interaction,. let us consider what happens to a wave as it runs up a natural beach, and contrast that to the same waves breaking against a vertical seawall. On a beach, the wave gradually breaks as it moves into shallower water. In the process, sediment is picked up from the bottom and moved onto the beach face. As the uprush of the wave slows, sand is deposited on the beach. As the wave swash stops on the beach face and runs back to the sea, some of the water is absorbed into the beach. As a result, not as much water moves seaward, and the return swash is less effective in picking up and removing the sediment that was just deposited - thus, the beach accretes. Through time, the slope of the beach adjusts to the point that landward and seaward transport balance one another and the beach stabilizes.

On a shoreline "protected" by a seawall, the sequence of a strong wave uprush, deposition of sand on the beach and a gentler backwash is modified. Consider, as an analogy, a ball striking the cushion of a billiard table. It will come off the cushion with nearly the same speed it entered. The same thing happens along a seawall. We must add to this scenario the facts that 1) the incoming wave has already done all the work of suspending the nearshore sediment and 2) the quick reflection of the wave off the wall does not provide an opportunity for the sediment to settle out. Therefore, the reflected wave is free to use all of its energy to move that sand away from the shore. In combination with the turbulence that is generated around the base of the wall, the net result is severe erosion that will lower the substrate to a depth below which the incoming waves are no longer efficient in suspending sediment.

These are offered only as simple examples for the sake of illustration. Accretion to the east of a groin and erosion to the west should not be taken as a hard and fast rule. Our coastline is very jagged, and waves can be bent and redirected such that a very complex transport pattern results. Likewise, a seawall should not always be ruled out as a defensive structure. Sometimes, the need for shoreline stabilization is so eminent that a wall is the only realistic option. Also, there are strategies that can mitigate the effects discussed above (for example, placing the seawall on a solid, rocky substrate). In both instances, the answer lies in careful consideration of the existing natural forces and the changes that are likely to result from the use of a particular structure. A careful analysis of the nearshore wave field under both day-to-day and storm conditions should be completed before considering any coastal modification.

What Can We Do About Erosion?

Providing examples of every type of erosion problem and solutions to each are far beyond the scope of this short paper. In the Workshop, case histories have been provided that illustrate the kinds of problems that most commonly occur and the solutions that worked under that particular set of circumstances. As a general point of reference, we have assembled Table 1 which briefly outlines the types of erosion problems that are most common in the U.S. Virgin Islands, the processes that are involved and possible remedies for them. Beyond that, the best advice that we can offer is to consult with a trained professional before attempting even what may appear to you as a benign modification. I was recently asked to comment on possible causes of and remedies for a new and sudden episode of beach erosion on St. Croix. After examining the beach, I suggested a program of aggressive beach revegetation. I was summarily informed that the owner had just spent considerable effort and money to pull up the existing vegetation as the owners of the property wanted an open, sandy beach and not a lawn - my solution was clearly not acceptable to them. This kind of ignorant practice, more than any other, has traditionally lead to the problems that we now face. The laws of physics are the only ones that we cannot break without sure punishment.

Beach Nourishment as an Option

From the introductory discussion of erosion as an imbalance between sediment coming in and going out, we can deduce that erosion on a particular beach is necessarily being offset by accretion somewhere else. Corollary to this idea, any engineering measure that causes sand to be deposited on your beach necessarily robs another site. As a result, the only way that you can circumvent this relationship (but still only on a local basis) is to bring in sand from an outside source - beach nourishment.

While preferable to most complex engineering solutions, there is a downside to this approach. First, it is expensive. Sand from off-island costs in the vicinity of $35 a yard. Therefore, even a modest nourishment project of 500 cubic yards will cost $17,500 for the sand along. To this, you must add handling costs, permitting fees and the studies that are necessary to obtain those permits. From a philosophic point of view, you are still robbing sand from somewhere else to solve your problem. And finally, you are probably committing to a long-term program of successive renourishment.

Table 1. Common beach-erosion problems and their remedies.

Cause of Erosion	Factors Involved	Remedy
Sea-Level Rise	Natural forcing functions; Global Warming	Stay out of its way; build with common sense
Seawall	Scour at the base of the wall; Preferential seaward transport of sediment	Foot seawall in rock Foot seawall deep enough to prevent undercutting Design wall to minimize scour
Breakwater	Reduces transport along the shore that is protected by the structure; can cause erosion downdrift	Use only in areas where downdrift shoreline is rocky (i.e., not subject to erosion)
Groin	Block alongshore transport	Use only in areas where downdrift beach is not sensitive (e.g., rocky or no development)
Vegetation Removal	Destabilization of the substrate, making it more susceptible to erosion	Don't do it; in areas where erosion is already a problem, undertake an aggressive revegetation program
Offshore Dredging	Creation of a hole that Mother Nature wants to fill. If it is close enough, your beach will provide the fill Modification of offshore wave patterns that become focused on your beach	Avoid nearshore dredging
Destruction of offshore reefs	Removal of protection from waves	Ensure that your project does not cause damage. If the problem already exists, then protection must be re-established.

Aside from the more altruistic aspects of the decision-making process (e.g., finding a supply that has not caused environmental damage at that locale), there are several important considerations in designing a working nourishment program. First, the sand must be of a proper size that it will remain on the beach. As a rough rule of thumb, do not put anything on the beach that is finer than what Mother Nature left there. The reason that the existing sand is there is that ambient waves could not pick the material up and move it away. Anything finer will disappear quickly. There are simple engineering tests that can be performed to approximate the fate of your chosen sand. Ambient wave and current conditions also need to be understood. This is important from a standpoint of understanding where your sand might go under extreme conditions and what adverse environmental impacts it might have. Consider, for example, that seagrass tends to stabilize the sand in the immediate offshore zone of many island beaches. Extreme levels of sedimentation can bury those grasses, thereby removing their stabilizing effect and opening your beach to increased erosion. Offshore reefs that now provide protection for your beach, if killed, will quickly be "eaten away" by the countless organisms that live on the reef and grind away at dead substrate to make their living in the reef economy. As a result, your beach will be exposed to increasing wave attack and will erode at an even greater rate.

This discussion closes with two points. First, beach erosion is not necessarily a bad thing. It is part of the natural waxing and waning of any shoreline comprised of loose material. The problem arises only when a man-made structure is put in the way of this process. A beach may come and go as part of the natural cycle. The end result is a stable beach over a long period of time. However, a building or other structure that is built on the beach and destroyed during the erosive cycle will not repair itself when the beach comes back. Erosion is not the problem; man-made structures put in its path are what we are trying to avoid. Second, it cannot be stressed enough that a "qualified marine professional" is not just someone with an advanced degree whose business brings them in contact with the sea on a regular basis. Biologists have special talents that qualify them to address ecosystem-level effects. Coastal engineers have been trained to design structures that will withstand the physical impact of wave attack. And marine geologists generally focus on physical-oceanographic phenomena and their effects on coastlines and the sediments that make them up. Expertise in one of these areas does not necessarily qualify them to make informed judgments about everything that goes on in the marine environment. Choose your "experts" wisely.

VI
AGRICULTURE AND WETLANDS

* *Paper not available at time of printing.*

OVERVIEW OF AGRICULTURAL NONPOINT SOURCE POLLUTION IN THE U. S. VIRGIN ISLANDS

Olasee K. Davis

Cooperative Extension Service/Natural Resources, University ofthe Virgin Islands, Kingshill, St. Croix V. I. 00850

HISTORICAL REVIEW OF AGRICULTURE IN THE U. S. VIRGIN ISLANDS

At one time, the Virgin Islands had an extensive and luxuriant forest. During the virgin stage of these islands, the native Indians gathered wild fruits from forest and cultivated small plots of land. Land plots, however, did very little to alter the forest ecosystem.

By the arrival of Columbus in 1492, forest was still the dominant vegetation throughout the islands, with the possible exception of a few small wetlands and rivers. Between the 15th and 16th century, a drastic change took place by the European settlers that inhabited the Virgin Islands.

Large acreage of forest lands were burned for colonial agriculture development on St. Croix, thus changing the ecology of the island. Also, clearing of land on St. Thomas and St. John went through a similar phase for agriculture development.

Land clearing was made possible when African slaves were brought to the shores of these islands in the late 1600's. Slaves cleared the land by cutting the trees and setting them on fire. At this period, sugarcane plantations were established for agriculture production. By the mid-1800's, the island of St. Croix had 114 windmills and 144 animal or ox mills.

In the early 17th century, agriculture revolutionized the islands' economy. With this, soil erosion became a major factor in agriculture production. Plantation crops were planted on slopes and hillsides, causing considerable erosion of the already thin tropical soil. Furthermore, the repeated burning of crop residue degraded the soil further by destroying its structure and reducing its fertility.

At this time, the European settlers realized that in order to continue to make a profit from the land, they would have to implement conservation practices. As a result, St. Croix's rolling hills were plowed along the natural lines of the land to keep the soil from washing away, while on St. Thomas and St. John, terraces were built along the hillsides to reduce further soil erosion.

Techniques in land use, combined with engineering and management practices, were thoroughly developed and well known in ancient times before the first Europeans set foot in these islands.

Today, it is proven through both scientific tests and the experiences of millions of farmers in many parts of the world, that contour practices, designed to fit the topography of the land and combined with soil-saving rotation planting and proper fertilization, provide protection to the soil, conserve water for plant growth, and raise yields of cultivated crops in many parts of the world.

Between the 1780's and 1800's, St. Croix became the richest sugarcane island in the Caribbean in addition to indigo, tobacco, and cotton. The 375 plantations on St. Croix flourished as produce was exported to Europe. It was at this time that the island was called the "Garden of Eden or Bread Basket of the Caribbean." However, the prosperity of agriculture production in the Danish Virgin Islands lasted only for a short time.

After more than 200 years in which the ownership of the Virgin Islands changed several times, Denmark encountered serious problems. Problems occurred when St. Croix was controlled by the British for a brief period of time. In 1803, the slave trade was abolished. Other problems arose when natural disasters such as earthquakes, tidal waves, hurricanes, droughts, and political upheavals and wars in Europe worsened the Virgin Islands economy. By 1848, he slaves received their physical emancipation.

A few years later, in 1917, the United States purchased the Virgin Islands from Denmark. Since then, the agriculture industry in the Virgin Islands changed drastically. Prior to the emancipation of the slaves in 1848, the island of St. Croix was cultivated from the beaches to the hilltops. There were some 30,000 acres of farmland devoted to sugar cane and other important crops.

Back then, sugar commanded up to $2.00 per pound in the world's markets, and under these circumstances the one crop economy was profitable. In 1966, sugarcane production phased out in the Virgin Islands and agriculture shifted from cropping to livestock production. Today, dairy and beef cattle are the Virgin Islands' two largest agricultural industries, primarily located on St. Croix.

THE EFFECT OF NONPOINT SOURCE POLLUTION ON AGRICULTURAL LAND

In agricultural areas of the U. S. Virgin Islands, the major nonpoint source pollution are land clearing, sedimentation, overgrazing, and to some extent the misuse of pesticides and fertilizers.

LAND CLEARING

Of the earth's land surface, 43 percent is occupied by rangeland, 11 percent by farming, 31 percent by commercial forest, and 15 percent by ice. In the Virgin Islands, approximately 75 percent of the agricultural land is devoted to animal husbandry with St. Croix having 92 percent of the grazing land.

The majority of this land, however, is covered with shrubs and bushes which reduce the productivity of animal production. Poor pasture management leads to undesirable species such as Casha (*Acacia* spp.), which dominates most of the Virgin Islands pastureland.

Thus, farmers find it necessary to clear the land in order to increase forage production for animal consumption. Oftentimes, however, lands are indiscriminately cleared by removing desirable plants with topsoil leaving the land bare, which is probably the worst thing that can be done.

It is important to leave vegetative cover on the land in order to protect the topsoil. The energy of falling raindrops is expended directly on the soil surface when land is cleared of every vegetation. During rain, the soil surface seal forms quickly and soon water run off at a maximum rate.

SOLUTIONS FOR CLEARING LAND

1. Avoid clearing land during the rainy season.
2. Leave trash on the land to reduce soil erosion.
3. Maintain as much permanent-type grazing grass as possible.
4. Plan and follow a weed control program.
5. Follow recommendations closely in establishing pasture (Experiment Station scientists and Cooperative Extension Service Specialists will provide recommendations when needed).

SEDIMENTATION

Sediment is made up of tiny soil particles that are washed or blown into guts, streams, eventually end up in the sea. Sediment is also one of the most damaging pollutants on agricultural land in the Virgin Islands, and nonpoint source pollution. Loss of soil by washing and blowing usually follows deterioration of vegetation. As soil becomes less abundant and increasingly compacted with misuse of the land, decreased water infiltration and increased runoff are inevitable.

On many pasturelands in the Virgin Islands, especially slopes and grazing land near the coast, gully erosion is visible. It occurs, either where runoff from a slope increase sufficiently in volume or velocity to cut deep incisions, or where the concentrated water flows long enough in the same channel to develop deep incisions in the soil.

Often gullies develop in natural depressions of the land surface where run-off water accumulates over a period of time. Gullies are often started by ruts or tracks up and down hills by the movement of machinery or livestock. With gullies, sediment is carried or transported picking up soil particles and disposing it in farm ponds or along the coastlines.

Although these problems are visible and easy to understand, other nonpoint source pollution problems associated with sediment are less obvious. For example, nutrients and pesticides can become strongly bound to sediment, especially fine soil particles, and can be carried with it to surface and ground water. These pollution sources will be discussed later.

SOLUTION FOR SEDIMENTATION

1. Control erosion with vegetation cover.
2. Livestock distribution on pasture land.
3. Ponds or dams construction on pastureland.
4. Practice conservation measures.

OVERGRAZED PASTURELAND

The primary purpose of pasture management is to prevent excessive grazing. This is especially important during the growing season for livestock farming in the Virgin Islands in order to increase the vigor and productivity of existing forage plants and eventually, to improve species composition. Animals have a major impact on the physical environment and the plant communities in which they are associated with (Davis, 1993).

This impact is also influenced by climate changes, land topography, and soil type which determine species of plants adaptation to different areas of the islands. Since most pastureland are made up of complex plant species, grazing must consider availability and palatability of the vegetation to maintain healthy animals.

Animals will not graze all individual plant species uniformly unless the pasture is overgrazed or grazing is carefully controlled to maintain plant vigor throughout the growing season. Also, with a given site, different plant species will maximize their growth at different times of the year.

As plant community develops, there is a continual change in the relative proportions of different plant and, therefore, a continually changing availability of forages (Mott 1960). If grazing is unmanaged or managed without consideration of the dynamic nature of the plant ecosystem, some forages will be grazed heavily by animals while others are lightly grazed or not grazed at all during the growing season.

This has been the case for years in most pastureland in the Virgin Islands. Desirable forages such as guinea grass (*Panicum maximum*) are at a disadvantage because of differential grazing will lose to the more undesirable plants. This will change, and usually reduce, the productivity of pastureland.

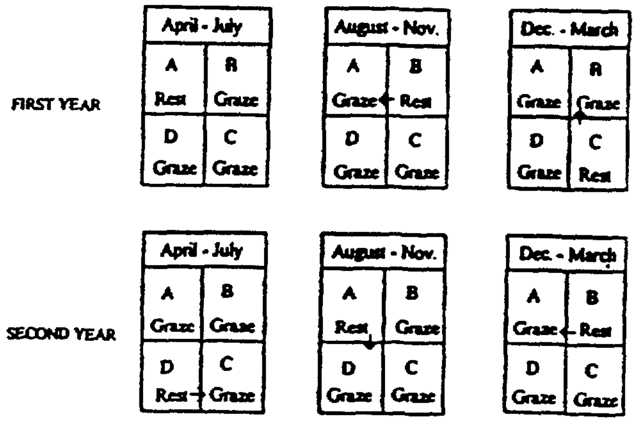
Thus, many pastures in the islands are overgrazed and invaded by plants that affect the performance of animals nutritionally to produce beef or milk. Such undesirable pasture plants as (*Crotalaria retusa L.*), Maran (*Croton riaidus*), and Wild physicnut (*Jatropha gossypifolia L.*) are indicators of overgrazed pasture land.

Overgrazing of pastureland in the Virgin islands has a major impact on land thus contributing to some level of nonpoint source pollution to surface or ground water supplies. Livestock affect watershed properties by removal of vegetation cover and through the physical action of their hooves. Reduction in vegetation cover of pasture can increase the impact of raindrops, decrease soil organic matter, soil aggregates, and increase soil crusts.

The primary effect of hoof action is the compaction of the soil surface. As a result, it decreases water infiltration rates, increases runoff, and soil erosion. Livestock also affect water quality. Fecal wastes from livestock grazing can be a sizable pollution problem in range watershed management (Holecheck, Pieper, and Herbel 1989).

To avoid such problem is to control the number of livestock, distribution in pastures, and attract livestock away from guts or stream areas. Grazing systems can help improve livestock distribution, and pasture forage conditions by protecting plant during critical growth periods, and can improve livestock performance by ensuring that plants are utilized at the best times of the growing season. The chart below shows one of many grazing systems that can be used locally for livestock production.

Four-Pasture Merrill System



Livestock concentrate on most nutritional plants when first placed in a fresh pasture. When these plants are grazed, they then graze less nutritional plants; thus, the nutritional level of their diet goes down. To overcome, speed up moves.

GRAZING SOLUTIONS

1. Implement grazing systems that will create and/or maintain good pastureland.
2. Control of space or how much area is to be grazed. This is done with fences, either permanent or temporary.
3. Control of time. How long the area is to be grazed or rested.
4. Control of numbers, or how many animals are to be placed in the area to be grazed.
5. Control of the animal. The farmer must be able to place the animal where and when he wants, for as long as he wants.

PESTICIDES

"Pesticide" is an umbrella term that covers a wide range of chemicals such as insecticides, fungicides, and herbicides. The use of these agrichemicals help the Virgin Islands farmers to produce high yields of crop, but pesticides could also provide a pathway for toxic pollutants to our ground water if they are used incorrectly.

Proper application of pesticide and operation of equipment are important to protect the applicator as well as the environment. The prevention of nonpoint source pollution by pesticide concentrates, spray mixtures, or wastes is also essential in protecting the environment.

At this moment, pesticide is not a major environmental problem as a nonpoint source pollution. Most Virgin Island farmers practice sustainable agriculture. However, the potential for pesticides to become a serious environmental problem is there. Those who use pesticides need to understand the chemical properties and how they should be applied in order to protect our natural resources.

The University of the Virgin Islands Cooperative Extension Service conducts classes both in the private and commercial category for pesticide applicators who want to become certified. By using pesticides wisely and applying them correctly, the responsible pesticide applicator can use these chemical for the benefit of the environment.

FERTILIZER

As crops grow, soil nutrients are utilized to produce food. On the other hand, significant amounts of nutrients are removed from the soil when crops are harvested and not recycled back to the soil. Thus, nutrients such as nitrogen, phosphorus, and potassium are essential parts of the agriculture industry in the Islands. These nutrients may be added to the soil in the form of fertilizer, decaying vegetation, or manure.

Fertilizer is not a major nonpoint source pollution in the Virgin Islands agriculture industry. But every step should be taken by farmers not to misuse fertilizer on farmland. All form of nutrients such as manure, legumes, and fertilizer should be managed properly to meet the needs of crop nutrients and reduce the chance of nutrient loss to surface or ground water.

CONCLUSIONS

The risk of agricultural nonpoint source pollution can be significantly reduced by more prudent application of land clearing, overgrazing, nutrient, pesticide and by good overall land management. I personally believe that conservation practices of agriculture provide environmentally and economically sound farming techniques for the Virgin islands farmers. Finding solutions to environmental pollution can only be solved when we recognize the importance of managing our natural resources properly.

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HOW TO MANAGE WASTEWATER AND RUNOFF FROM CONFINED ANIMAL FACILITIES

JEFFREY J. SCHMIDT

United States Department of Agriculture
Soil Conservation Service
United States Virgin Islands Field Office
St. Croix, USVI 00851

The United States Virgin Islands confined animal facilities are very unique. Two categories are the most common and at the same time very different. In one category, there are less than a few dozen farms that have large enough systems (usually more than 75 head of stock) that would support controls or measures that are engineered, designed, and constructed, but may require large sums of monetary support. Most commonly these herds are either dairy, beef, swine, sheep, goats, or poultry. This is not to say that all large facilities have water quality problems, but rather the potential is greater.

On the other hand is the category where there are virtually hundreds of small operations of confined animals. The animals common in this group are more of a mix than the preceding category. Again, each situation is different. Five goats can be more hazardous than twenty cows if the confinement location is not appropriate.

Of course there are the herds that just roam, graze, or browse. Common to this group are horses and goats. It should be noted that any animal can be a roamer, should gates be left open or fences be in dire need of repair. Certain animal types are common to an area in the Virgin Islands, rather than the rule. In other words, these domesticated animals do not roam from coast to coast in search of food or forage. But rather stay in an area big enough to support the herd, and from there they do not venture. Commonly referred to as the lands "carrying capacity". This refers more directly to the plants ability to survive grazing pressure. These roamers can also be detrimental to humans, other livestock herds, and to themselves as well. It just depends on where the feces fall.

Wastewater management problems often arise when livestock are added to a farm without increasing the land base. When land and animals are out of balance - that is the waste produced greatly exceeds the capacity of the land to utilize the nutrients in the waste product - we find that water quality problems begin to show. Unfortunately, these problems can go unnoticed for a long period of time. Some examples could be fish kills, odor, drinking water contamination, or even bacteria related diseases spreading to humans. A common bacteria in these cases is E-Coli.

Careful observation and common sense can often determine whether a given farm practice is likely to cause the quality of water to deteriorate or affect the environment. The quality of water can be adversely affected if manure runs into streams or guts as a result of land application, spillage, storage overflow, or deliberate dumping.

Increased bacterial counts can indicate this has happened. Several illnesses can be attributed to high bacteria counts in water systems. Common are typhoid, hepatitis, bronchitis, and even urinary infections. All of which can be fatal if not treated. More often than not, rainfall transports the waste products into the groundwater and/or across the soil surface. Nutrients in manure applied to the soil at rates that exceed the soils and plants ability to breakdown or uptake the nutrients, can leach into groundwater or be carried away off site with runoff water and eroded soil to the sea. This off site transport is often referred to as non point source pollution. Increased nutrients like nitrogen in the groundwater can cause drinking water problems for water well users. Nitrate poisoning is possible which can be serious, but more so to infants.

The reasons for developing and maintaining a sound wastewater management plan include: 1) environmental benefits to everyone, 2) economic benefits to the farmer, and 3) compliance with laws and regulations concerning environmental quality.

Let us explore managing waste from a large animal facility first so that we can be introduced to the general principles of waste management or runoff control. The two are rather synonymous. A component of waste management is controlling runoff to and from the confined facility.

A system to manage waste and runoff from a confined animal facility must be developed using a total systems approach. A total system accounts for all the waste associated with an agricultural enterprise throughout the year from production to utilization. From extra feed to overflowing watering tanks. From parlor flushing to excess bedding. From manure storage to application. Everything. In short, it is the management of all the waste, all the time, all the way through.

With this in mind we begin the process of inventorying all of the resources associated with the agricultural enterprise. This list is not all inclusive. The accuracy of identifying the resources allows more functional alternatives to be developed. Some of the data you collect can be easily measured, such as the number of acres available to spread waste. While other data may be less tangible, not easily measured, but rather rely on personal discussions, observations, or just plain common sense judgement.

A brief list of the inventory needed includes: type of livestock, type of operation, breed, size (number of stock, ages, weights, replacements), feeding components, site location, bedding, present facility, land availability, soils, topography, rainfall, geology, crops, labor availability, equipment availability, level of producer management, adjacent land use, livestock travel routes, confinement days, laws and regulations, utilities, landscape resources, flexibility, expansion opportunities, producer financial situation, etc, etc.

Once a thorough investigation of the resources is complete, arrange the information into six categories for interpretation, analyzation, and evaluation. They are: 1) Production, 2) Collection, 3) Storage, 4) Treatment, 5) Transfer, and 6) Utilization. Once broken down into one or more of these categories, alternatives can be selected that best fit the site conditions, livestock operation, and the producers objectives. When selecting and considering alternatives, always keep in mind that the purpose of managing animal wastewater is not to detrimentally affect water quality or the environment.

Components of the previously mentioned categories are more commonly known as "alternatives available to manage wastewater and runoff". They include, but again are not limited to: roof gutters, clean water diversions, dirty water diversions, alley scrapers, flush alleys, ponds, tanks, dry stack, lagoons, composters, solid separators, settling basins, pipelines, hauling equipment, pumps, push off ramps, irrigation systems, spreaders, commercial sale, refeeding, bedding, energy generation, artificial wetland wastewater treatment, etc, etc. This last alternative is excitingly new for the Virgin Islands and may hold great promise because of our shrinking agricultural land base.

Moving to a smaller operation, all the principles of planning and data collection are the same, you just do not have the land base available and more common, the financial capital to build the same controls as a larger operation. Some items are suggested for larger operations as well. These happen to be virtually free from monetary input. The first thing that can be done is to reduce the stock size. Prevent stock from entering watering facilities, streams, ponds, and diversions, rotate pastures, rearrange feeding areas away from steep slopes, create buffer strips, repair fencing, feed in bunks not on ground, and keep thinking. Common sense approaches can be found every day. Your only limitation sometimes can be your imagination. Animal waste management is not a one day event. Conditions are constantly changing, as you must, in any farming or animal management enterprise.

Managing wastewater and runoff from confined animal facilities is dynamic with many alternatives being available as well as many problems that can be created. Because of the variety of alternatives, solutions, conditions, and situations, that the management system must be incorporated, no one procedure can be followed to arrive at a one system design. One recommendation may be ideal for one farm and completely inappropriate for another. Alternatives are always available. Whether they are the ones that fit your operation, or are feasible for you, may be a completely different matter.

In conclusion, the most important item is to recognize a problem, even a potential problem, and to take positive steps to protect, restore, and improve the environment - specifically the quality of water in this case. Out of sight is not out of mind. Remember, to look in your own backyard before you criticize across the fence.

SUSTAINABLE AGRICULTURE IN THE VIRGIN ISLANDS

Louis Petersen, Ph.D

Cooperative Extension Service, University of the Virgin Islands, St. Thomas, VI 00802

According to the Food, Agriculture, Conservation and Trade Act of 1990, Sustainable Agriculture is an integrated system of plant and animal production practices having a site-specific application that will, over the long-term, satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agricultural economy depends; make the most efficient use of non-renewable resources and on-farm/ranch resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm/ranch operations; and enhance the quality of life for farmers/ranchers and society as a whole.

Simply stated, sustainable agriculture refers to agricultural systems that are designed to be productive while being ecologically sound, economically viable, socially just and humane. These systems are comprised of practices such as composting, inter-cropping, multiple cropping, crop rotation, terracing, diligent record keeping, appropriate varietal selection, and the use of drip irrigation. While some of these methods and technologies are new to some farmers and home gardeners in the Virgin Islands, some have long been in use as a consequence of tradition or necessity.

Terracing refers to the construction of earth embankments, channels, or combinations of both across the slope of the land. This has been practiced for hundreds of years in the Virgin Islands, especially on St. Thomas and St. John where the terrain is hilly and often very steep. The most common type of terrace constructed by local farmers employs the use of rocks to contain and stabilize the soil. This makes good use of the many, available rocks which characterize our soils. Terracing serves to reduce soil erosion and runoff as well as create a more manageable working area for the farmer since the area is made to be level.

Another practice which helps to conserve our natural resources is mulching. This involves the use of synthetic or organic materials such as straw, grass cuttings, leaves, manure, wood chips, plastic or woven fabric to cover the ground surface around plants to conserve soil moisture and control the growth of weeds. Mulched plants need water less frequently than non-mulched plants. Mulching also reduces runoff and soil erosion since the materials used provide a protective covering for the soil. Organic materials such as manure and grass cuttings are more commonly used in the Virgin Islands compared to synthetic ones. Organic mulch materials gradually decompose and enhance soil structure and fertility. On the other hand, synthetic options such as plastic are more durable and can last from one planting season to the next. Biodegradable plastics have been developed and have great potential usage for Virgin Island farmers who avoid the use of conventional grades of plastic.

The importance of proper varietal selection of crop types is often underestimated by farmers and home gardeners in the Virgin Islands. By choosing the appropriate varieties of fruits or vegetables in production systems, lower inputs of pesticides, fertilizers, and even water may be necessary. Modern varieties which are tolerant to diseases, insects, existing soil conditions, and drought should be used whenever available.

Crop rotation refers to a system of planting crops in a compatible and complementary manner in order to prevent the potential build up pest populations on a given farm site. It is well known that the potential for disease and insect problems (especially soil - borne problems) increases when the same or similar crops are grown successively on the same field. Crop rotation relies on the diversity between plant types to interfere with the natural life cycle of insects and disease causing organisms. Consequently, the quantities of pesticides used for crop production can potentially be reduced, and therefore, their environmental impact. In addition, when the same or similar crops are repeatedly grown on the same plot of land, soil fertility levels decline due to the constant demand for the same quality and quantity of nutrients. This usually leads to unnecessary applications of fertilizer to restore soil fertility. Crop rotation uses plants which are appreciably different so that soil nutrient reserves are not exhausted, resulting in "tired soils".

Similarly, the practice of inter - cropping is based on the principle that similar plant types attract similar pest problems while a diversified population of plants guards against this. Hence, inter - cropping involves the growing of two or more totally different species together in the same field. As with crop rotation, to reduce the potential of a pest outbreak is to reduce the potential environmental impact of pesticides. Practically all farmers and home gardeners in the Virgin Islands traditionally practice inter - cropping due to the unavailability of another very limited and expensive resource -- land. Farmers and gardeners must use their land prudently in order to get as much production as possible from small acreages.

Another important practice which needs more attention on the part of Virgin Island farmers is record keeping. Good record keeping (in conjunction with soil testing) can help farmers decide if, for example, a fertilizer application is necessary. Fertilizer applications are often made at random without without considering the date of the last application or the current fertility status of the plot in question. This can result in unnecessary applications of fertilizers which, in turn, can eventually contaminate our aquifers. A good record keeping system also documents a crop history (i.e. the sequence in which crops have been planted on a farm site). Such information can facilitate an effective crop rotation system which, as was mentioned previously, is a pest control measure and which prevents the exhaustion of soil reserves.

Fresh water is quantitatively a very limited natural resource in the Virgin Islands. Therefore, measures must be taken to make the most efficient use of this precious commodity. Many producers in the Virgin Islands still supply water to their crops by means of the "conventional" hose or a bucket. Besides causing mechanical damage to plants, this system makes wasteful and inefficient usage of water. Most of the applied water never reaches the plants for which it was intended, and instead contributes to runoff, erosion and sedimentation of soil particles. On the other hand, drip irrigation technology is strongly advocated for use in crop production since water use efficiency is maximized. This is accomplished by gradually supplying plants with small amounts of water in a dripping manner through tubes for periods of time. This ensures maximum uptake and utilization of the water by plants, and there is no resultant runoff, soil erosion, or sedimentation. The use of drip irrigation systems as a production practice is gradually becoming more commonplace among Virgin Island farmers.

Composting is the practice of managing the decomposition of organic matter such as plant or animal residue or waste which results in a rich, humus material which can be used as a fertilizer, mulch or to improve soil structure; Composting, therefore, represents a means of recycling the otherwise refuse by-products of agricultural activity and re-incorporating these organic materials into continued agricultural production systems. The concept of a properly managed, scientific system of organic matter decomposition is relatively new to crop producers in the Virgin Islands, but should be strongly encouraged.

Although the examples given herein are from the perspective of crop production, sustainable agriculture is also practiced in livestock production. For example, poor record keeping in pasture management can result in overgrazing, and thus, poor management of animal manure, and soil erosion.

Sustainable agriculture represents one of many initiatives to address the issue of environmental preservation. With the assistance of the agricultural agencies of the Virgin Islands, our farmers can also make significant contributions toward the conservation of our natural resources in order to ensure tomorrow's food production.

THE ENVIRONMENTAL AND ECONOMICAL BENEFITS OF WETLANDS

Algem Petersen

Department of Planning and Natural Resources, Coastal Zone Management Program, St. Thomas, U.S.V.I.

In the ecologist's language, wetlands are known as ecotones, or transitional areas - sandwiched between permanently flooded deepwater environments and well-drained uplands - at one edge they are predominately aquatic (very wet) and at the other mostly dry (1).

Section 404 of the Clear Water Act defines wetlands as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (2).

Normal circumstances are considered to be:

1. The soil and hydrological conditions that would exist if the vegetation were not altered or removed.

2. Cropping or cropping history is not the normal circumstances.

In the recent press release from The White House Office on Environmental Policy, on 'New Federal Wetland Policy', Carol Browner, Administrator of the U.S. Environmental Protection Agency, states that "American wetlands are currently being lost at a rate of nearly 300,000 acres per year". Another section of that release entiled "Protecting America's Wetlands: A Fair, Flexible and Effective Approach" further states "The Nation has lost nearly half of the wetland acreage that existed in the lower 48 States prior to European settlement. The Nation's wetlands continue to be lost at a rate of hundreds of thousands of acres per year due to both human activity and natural processes. This continued loss occurs at great cost to society" (3).

During the last thirty years researchers have discovered the significant, irreplaceable ecological values and roles that wetlands provide to communities. The term heritage value has been used to describe the importance of wetlands as educational resources, as repositories of biodiversity, as sources of aesthetic experience, and as, simply existing natural phenomenon. The importance of the goods that wetlands produce has been extensively documented.

ENVIRONMENTAL BENEFITS

Wetlands are considered among the most important ecosystems on the earth. They provide a number of benefits including nonpoint pollution control. Some of the roles of wetlands involve:

Flood Control:

They help to moderate - to control - extreme floods by absorbing water during heavy rainfall, then slowly releasing it downstream.

Erosion Control

Wetlands buffer shorelands against erosion. Wetland plants also bind soil with their roots and help to absorb impacts from wave action.

Fish & Wildlife Habitat

Wetlands are home to many commercially important animals like shrimp and crayfish. Young fish find in them a readily available supply of food as well as protection from predators, due to their fertile and protective nature. Nearly all the fish and crustaceans harvested commercially and half of the recreational catch depend on wetlands for food and habitat during part of their life cycle (1, 4). A large proportion of Federally listed threatened or endangered animals (45%) and plants (26%) depends directly or indirectly on wetlands to complete their life cycle successfully. They provide migration routes for wildlife through their natural areas along rivers and streams which are often "linear corridors", serving as bridges within and between remaining wildlife habitat (1). These quality wetlands are used by millions of migratory birds and waterfowl which use these ecosystems for food and shelter during the Spring and Fall migrations north and south, and for breeding and wintering grounds in summer and winter. These connected landscapes can also help to increase or maintain species diversity and population size of plants and animals; they also maintain genetic variation within these populations and provide predator-escape cover for movement between areas.

Improve and Maintain Water Quality and Quantity

Wetlands are important for maintaining and improving the quality while requlating the quantity of our water. Numerous studies show that wetlands remove sediments, nutrients and toxins from the water. Because of their function as removers of waste from both natural and human resources, they are sometimes described as "the kidneys of the landscape". They are natural water treatment plants; they help to purify water pollutants that may contaminate and diminish the quality of larger bodies of water (eg. the ocean). Wetlands also increase water quality by absorbing water in wet seasons, feeding it to surface and underground water storage areas and gradually releasing it through wells, springs, seeps or open outlets during dry periods (1,4).

Wetlands are extensively used for other activities such as boating, forestry and hunting in many parts of the world, and to a lesser extent here in the Virgin Islands.
Wetlands have also been appreciated and valued in the field of fine arts and literature. For centuries naturalist, landscape painters, photographers and writers have expressed their appreciation through their work; and we have all seen and enjoyed these pictures and paintings (1,4,5).

Despite their destruction and abuse, wetlands continue to provide us with valuable services. They form natural reservoirs, store flood waters, minimize the damage from severe storms, and provide a home for a wide variety of important plants and animals. To a large extent, the characteristics of wetlands and the manner in which they function are determined by what is happening in the areas surrounding those wetlands. To understand why this is so we must understand how hydrology controls wetland sediment supply and erosion; the availability of oxygen to the organisms that depend on it; the nutrient supply and biological production and the channels of access by migratory animals (Fig.1).

ECONOMICAL BENEFITS

Wetlands along the Atlantic and Gulf coasts are especially critical to the fishing industry in America and support a multi-billion dollar per year commercial and recreational fishing industry.

Commercial Fisheries:

A major part of the commercial fisheries catch in the U.S. is comprised of species that use wetlands as feeding habitat and as nursery. Each year, America's commercial fisheries harvest is valued at more than $10 billion. In the Southeast, an estimated 96% of the commercial catch and over 50% of the recreational catch consist of fish and shellfish that depend on coastal wetland systems. Some of these wetland dependents are bluefish, sea trout, shrimp, oysters, clams, blue and Dungenese crabs (Table 1).

Hunting and Trapping:

Wetlands contribute commercially to support a fur and hide harvest worth $300-400 million annually. Muskrat and beaver are the more familiar wetland fur-bearers. Muskrat pelts alone are worth over $70 million annually.

Recreation:

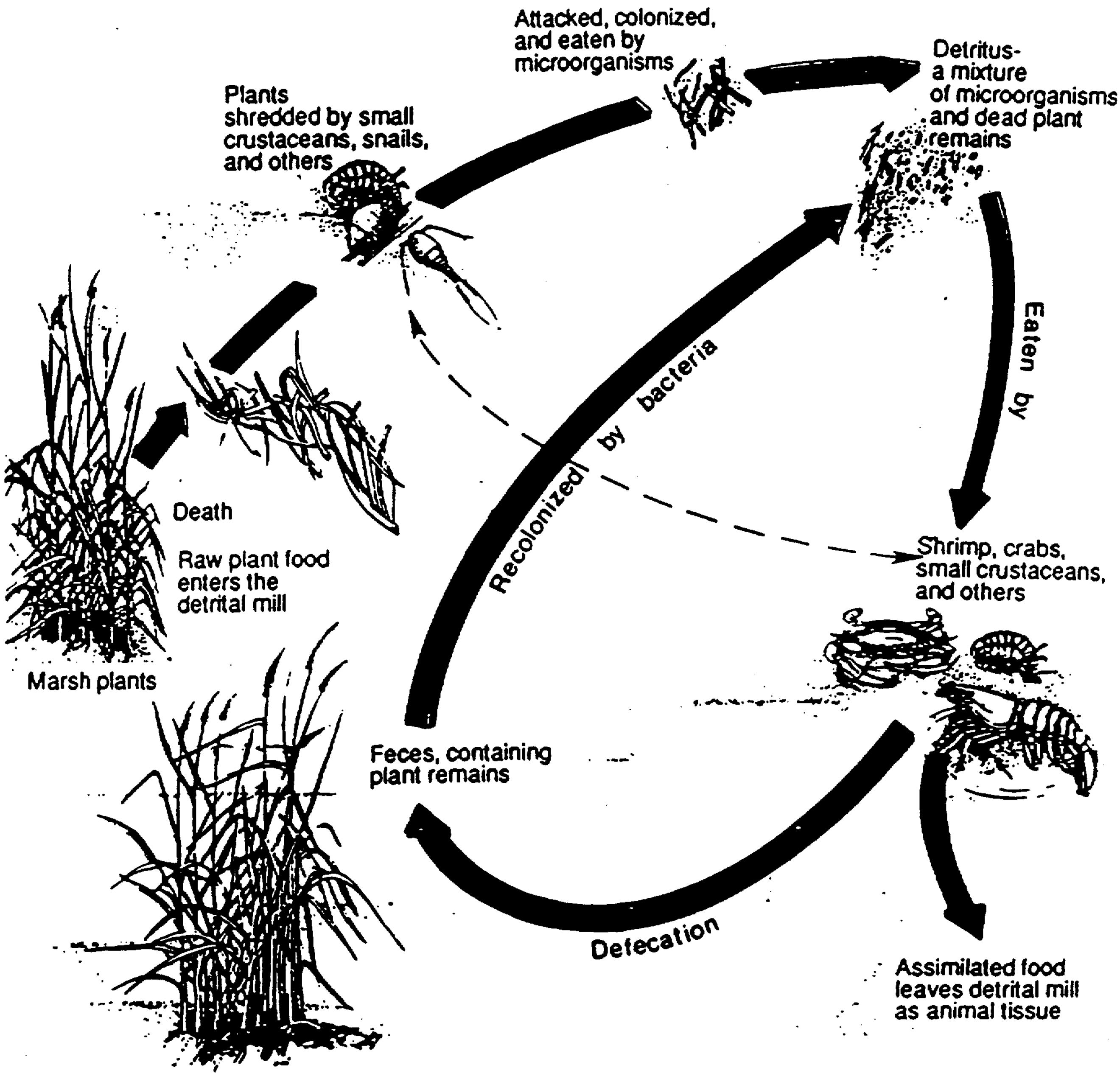
Wetlands are considered to be "wonderlands". Many recreational activities such as waterfowl hunting, fishing and crabbing, take place in and around wetlands. Observation and photography

of wetland-dependent birds entice an estimated 50 million people and they spend nearly $10 billion a year on their hobby.
Many people simply enjoy the beauty and sound of nature during their walk along these wetlands (1,6).

This new understanding of the value of wetlands has helped to increase awareness for the need to re-evaluate the effects of wetland loss. The White House press release also indicated that Federal wetland policy should be based upon the best scientific information available. It is crucial that we do the same here in the Virgin Islands. There are a number of people here in the territory who are interested in some type of wetland research project. To be complete and effective such project should include people representing different areas of the ecosystem, who are equipped to look at the different aspects of wetland activities:

* as an habitat
* the entire oxidation/reduction sequence
* hydrology
* soil type and
* plant life

WETLAND FOOD CHAIN



ar[illegible] grasses support the detrital food web. Small animals shred the dead grass, enabling microorganisms to colonize it and break it down chemically so that other imals can assimilate it and grow. Their waste products are recolonized by microbes and the cycle is repeated.

ur The fragile fringe: coastal wetlands of the continental U.S.

TABLE I

REVENUE DERIVED FROM WETLANDS IN THE U. S.

	($)
Commercial Fisheries	10 Billion
Hunting & Trapping	300-400 Billion
Recreation	10 Billion

TABLE II

COASTAL WETLAND AREA IN THE VIRGIN ISLANDS

ISLANDS	TOTAL	WETLAND	%
	Area (ha)		
ST. CROIX (9)	21,800	598	3
ST. THOMAS (4)	7,300	354	5
ST JOHN (7)	5,200	25	1

WETLAND

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VII
WINNING STUDENT ENTRIES AND CLOSING REMARKS

** Paper not available at time of printing.*

FINDING SOLUTIONS TO ENVIRONMENTAL POLLUTION

Alfredo A. Bough

All Saints Cathedral School, St. Thomas, USVI 00802

We, as humans, need to be aware of our environment. Nature and animals everywhere are very sensitive to changes in the environment including industrial chemicals and human wastes. Remember; we are a part of nature too.

We need to care about what happens to the trash other people haphazardly throw away. As a popular commercial on television advises "GIVE A HOOT, DON'T POLLUTE". This should be taken seriously and not pushed aside. We require education for ourselves and our children. This education should be incorporated into our schools and as well as in our households. Our youth of today depend on us to make this world a better place for them to live in.

One instance of environmental pollution is cars that we drive everyday. Carbon monoxide, the harmful culprit of pollution from motor vehicles, ascends in the atmosphere and in the air we breathe. Two problems are sparked. One, carbon monoxide can cause breathing problems and even lung cancer. Two, carbon monoxide adds to the warming of the earth or more commonly known as the greenhouse effect.

Raw sewage from pipes that are either broken or run-off directly into our oceans from which we get water and food is another instance. Instead of allowing this to happen we should use tax money more wisely and build more effective sewage and water desalination plants.

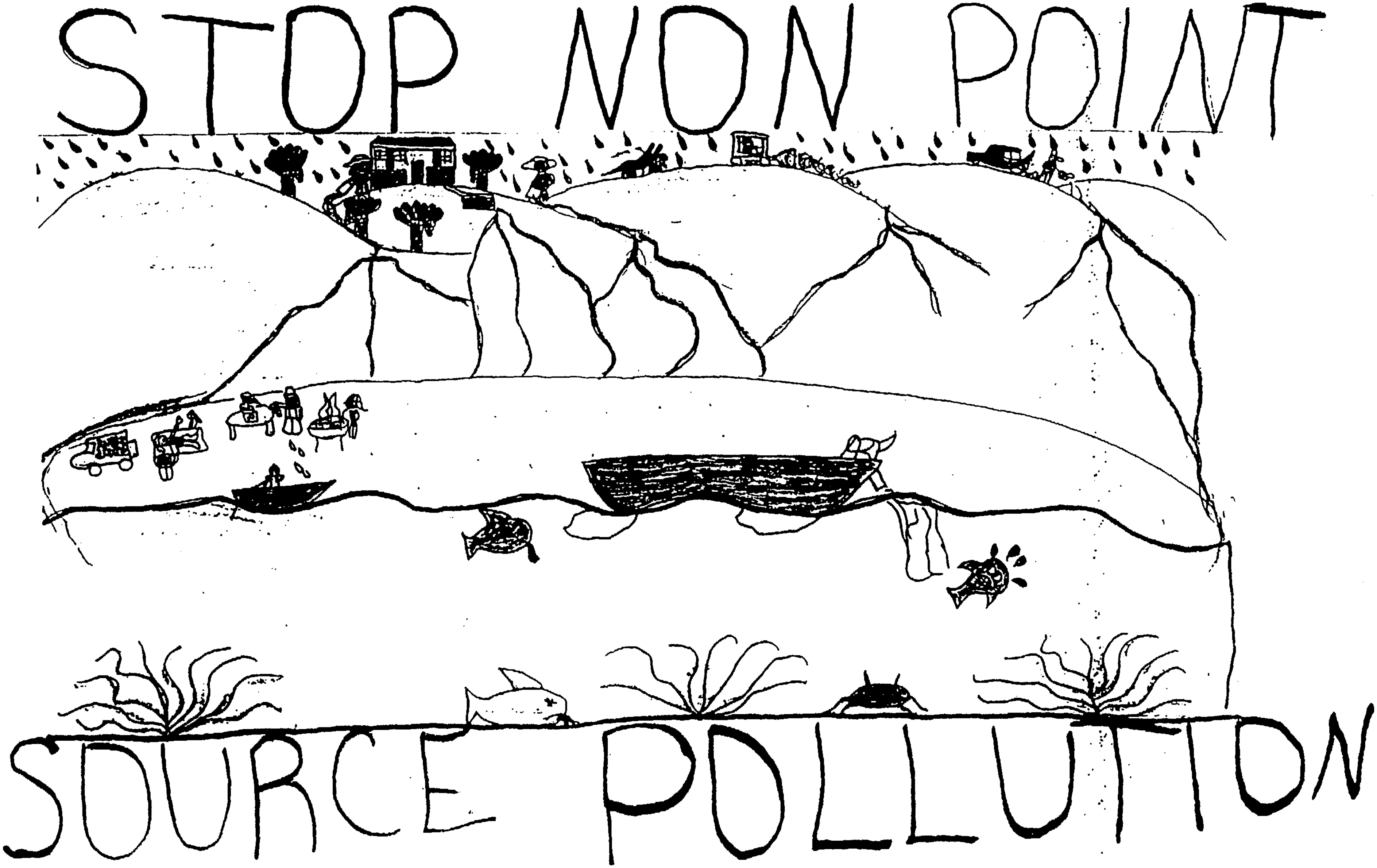
Household and automotive care products such as oil, grease, heavy metals, and other toxic chemicals can be found in urban stormwater runoff if not properly disposed of. This can cause disease and in some cases even death. Contamination of drinking water with sewage and hazardous minerals can stimulate many diseases such as typhoid fever, malaria, and infectious hepatitis. Farmers should use pesticides only when needed because it can kill fish and contaminate drinking water from runoffs.

Particularly in St. Thomas and coastal states recreational boating is also a problem. Spilt fuel, untreated sewage and trash discharged overboard, are not only hazardous to us and the environment but illegal, too.

We are all a part of the problem so all of us can help to solve it. everything we do can cause pollution, from fertilizers to engine oil, and paper plates to styrofoam cups. You name it and somehow it is a pollutant.
Here are some ways to clean up our island. Please keep litter,

pet wastes, and debris off our street and out of guts. Apply lawn and garden chemicals sparingly and according to label directions. Please dispose of oil, anti-freeze, paints, and other household chemicals properly. Clean up car lubricants and brake fluid. Don't wash them into the street or gut. Dispose of pesticide containers and rinse water properly. Maintain your septic system by pumping the tank at least once every three years. Reduce or prevent soil erosion on your property by not clearing vegetation or by planting native vegetation as ground cover and stabilizing erosion-prone areas (such as steep, unstable slopes). Minimize manure, fertilizer, and pesticide applications and time them according to when plants need these chemicals the most.

To help resolve the environmental pollution problem we can each do our share to remedy the problem. The aforementioned paragraph was a list of ways to "HEAL THE WORLD" and "MAKE IT A BETTER PLACE FOR THE ENTIRE HUMAN RACE". If these guidelines are followed our island will be a cleaner environment for us to live in.



STUDENT: Tishuana Hodge
SCHOOL: John H. Woodson Junior High

NOTE: Poster has been reduced. The actual poster is in color and can be seen at the Department of Planning and Natural Resources, Nisky Center, St. Thomas, VI

CLOSING REMARKS

Joan Harrigan-Farrelly, CZM Program Manager
Department of Planning and Natural Resources, St. Thomas, VI 00802

Good afternoon ladies and gentlemen. Over the course of the past two days, we have tried to pull together regulators, users and developers to discuss the problems and possible solutions concerning NPSP.

We heard from the novices who wondered aloud what NPSP was and we heard from the experts such as Mr. Kimball, Mr. Mc.Comb and our own Dr. Kojis and Mr. Giruad. We heard from the regulators both federal and local who told us what the laws , rules and regulations governing NPSP were and we heard from Dr. Ragstar who challenged each of us to deal with the problem from a personal level, from a behavioral level. For as Dr. Ragstar said only when we modify our day to day living habits, will we be able to reduce some of the problems and minimize some of the waste we have been accumulating.

We saw and heard from our youth their perspective on the problem and possible solutions through their posters and essay contest, and we heard from the Governor his commitment to protect and preserve our beautiful islands.

Some of the solutions presented include:

1) looking at our own personal behavior and looking at ourselves as of contributors to the problem, and therefore as the ones capable of solving the problem.

2) Revising our laws and statutes in terms of sewage disposal, earth change practices, septic systems, and agricultural practices.

3) Utilizing Best Management Practices as far as construction, agriculture, marinas, and golf courses are concerned.

4) Reviewing our earth change criteria more carefully and taking a closer look at erosion and sedimentation control plans that are presented, and then monitoring the progress of construction.

5) We heard that the soils of the Virgin Islands are not conducive to septic systems and a recommendation that all new housing development must use alternate sewage disposal systems by the year 1995. This means that our Public Works Department must have on line adequate, and state of the art sewage treatment plants, and that

private home owners and DPNR must also begin to investigate individual treatment systems, some of which were discussed today.

There were numerous other recommendations that came out in the various sessions, too numerous for me to summarize. However, we will try to compile all the recommendations and present them to you with a summary of the proceedings.

So, where do we go from here?, what will we, or how much will we commit ourselves, our departments, our agencies and our companies to solving this problem? Did we during the course of the last two days decide the problem was large enough to warrant our full combined commitment? From the presentations and open discussions, I believe that the consensus was that we will all strive to commit ourselves and our resources to remedying the problem.

I must add however, that such a problem cannot be solved by one agency alone, or by the government alone or by one company. Clearly from the discussions, we are all contributors to the problem and therefore it will take our collective efforts to solve the problem. In the same way that it took our collective efforts to bring about this conference.

Conferences like this are not easy to organize and so I would like to thank all those who worked diligently in organizing the conference, contacting the speakers, and getting the word out. But before I acknowledge all the conference committee organizers, I would like to single out one person Ms. Janice Hodge who worked tirelessly to ensure the conference ran smoothly. Mrs. Hodge you did a wonderful job and I'd like us to please give her a hand. Other members of the planning committee included Ms. Julie Wright-UVI Cooperative Extension Service, Ms. Marcia Taylor, UVI, Eastern Caribbean Center, Mr. Olasee Davis, UVI Cooperative Extension Service, Mr. Mario Morales, USDA Soil Conservation Service, Mr. Bruce Green , Caribbean Hydro-Tech, Inc., Ms. Algem Petersen DPNR, Division of Permits, Ms. Lynne MacDonald UVI Eastern Caribbean Center, and again last but not least, Ms. Janice Hodge Chair of the committee, DPNR, CZM program.

Allow me also to thank the Governor for opening our conference, Mr. Richardson for filling in for the Commissioner, all the presenters, those that came from far and near, the schools and students that participated in the poster and essay contest, Limetree Beach Resort and in particular Lex and his staff, and you the participants. For without you there could have been no conference.

Lets leave this conference today with renewed energy and commitment to working together to solve our problems, and to making these beautiful islands the paradise they can be.

Only with government departments joining hands with each other and the private sector and nongovernment agencies will we be able to come up with solutions that will benefit all.

I look forward to seeing you at next year's conference.

Once again thank you for your participation.

AUTHOR INDEX

* *Paper not available at time of printing.*